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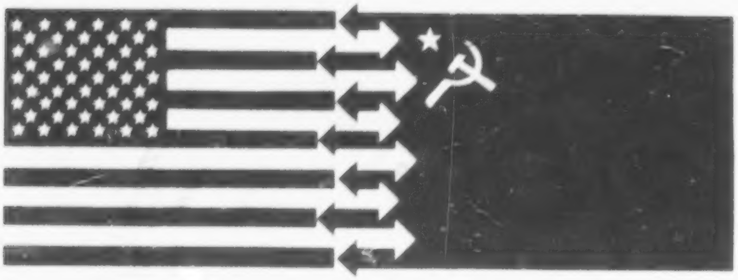

Science Policy: USA / USSR

Volume II: Science Policy in the Soviet Union

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SCIENCE POLICY: USA/USSR

Volume II

Science Policy in the Soviet Union

Paul M. Cocks

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INTRODUCTION

Beginning in 1972 the Governments of the United States of America and the Union of Soviet Socialist Republics signed a series of bilateral agreements for cooperation in various areas of science and technology, of which there are now eleven in number. The senior of these, the Agreement on Cooperation in Fields of Science and Technology, was signed by President Nixon and General Secretary Brezhnev in May 1972 and is implemented through a U.S.-U.S.S.R. Joint Commission on Scientific and Technical Cooperation, chaired on the U.S. Side by the President's Science and Technology Advisor. One of the twelve active Working Groups carrying out cooperative research under the Joint Commission is in the area of Science Policy, which in turn focuses on two major areas of mutual interest: the Planning and Management of Research and Development, and Fundamental Research Systems.

The present two-volume study, Science Policy: USA/USSR, prepared by members of the U.S. side of the working group, is based on the first phase of work in Science Policy by the group concerned with R&D Planning and Management,[1] which lasted from approximately 1973 to 1977. The goal of this phase was to build a base of information which could then serve to orient U.S. participants to more discrete and sophisticated analyses of the policy-making systems in the respective countries concerned with scientific and technical research; the principal mode of operation during this phase was exchange of visits, written information, reports, and specific questions and answers between the U.S. and Soviet members of the group. It became quickly apparent, although not to anyone's great surprise, that there would be a number of problems in emerging with satisfactory products, from information access and administrative difficulties to, perhaps most significantly, entirely different perceptions of the content of the study of science policy, incompatible terminology, and divergent analytical traditions, not to mention the important substantative differences in the making of science policy in the two countries. In many senses, we were speaking entirely different languages to one another and for this reason our initial progress was often slow and painful.

By 1976-1977, however, enough progress had been made to encourage U.S. participants to think about compiling what we had learned, both about ourselves and the Soviet Union, into monograph form in order to make this information accessible to the public at large. Again, not surprisingly, the job of compilation was beset by many of the same difficulties mentioned above. An initial summary prepared by Battelle Columbus Laboratories was reviewed and commented upon by U.S. participants, after which Mr. Nat C. Robertson, a distinguished technical administrator and research scientist with broad experience in the U.S. industrial sector, and Dr. Paul M. Cocks, a leading specialist on science policy in the U.S.S.R., utilized the data prepared by Battelle in writing the present volumes. The results, I believe, merit close examination by scholars, scientists, government and industrial officials, and the lay public.

The time and effort of an unusually large number of individuals went into vaious phases of this project. Nat Robertson and Paul Cocks deserve special praise for taking on the extremely challenging task of sifting through the mass of accumulated material, verifying data, and integrating it with their own expert knowledge to yield an intelligent and illuminating final product. The initial summary by Battelle Columbus Laboratories was, of course, highly instrumental in getting the study off the ground and the contributions of the Battelle staff are gratefully acknowledged. The information contained in the volume on the U.S.S.R. could not have been obtained in the first place were it not for the enthusiastic participation--which was severely tested at times--by the U.S. members of the Science Policy Working Group, most particularly its former U.S. Chairman, Dr. David Z. Beckler, and of the members of the Subgroup on R&D Planning and Management who participated in the project's first phase (in alphabetical order), Joseph Berliner, Lewis M. Branscomb, Paul M. Cocks, Murray Feshbach, Richard T. Gray, Herbert Levine, Franklin A. Long, Nat C. Robertson, Lowell W. Steele, and Robert L. Stern. The staff of the Arlington, Virginia office of SRI International assisted with the final editing and preparation of the manuscript. Although these studies are not official publications of the U.S. side of the working group and only their authors are responsible for their content, I wish to take this opportunity to thank all those who assisted in their preparation. Financial support for the project was provided through the National Science Foundation.

William D. Carey
U.S. Chairman, U.S.-U.S.S.R. Working
Group on Science Policy

June 1980

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[1] Until 1979 there were four subgroups of the Science Policy Working Group: R&D Planning and Management, R&D Financing, Training and Management of S&T Manpower, and Systems for Stimulating the Development of Fundamental Research. Other publications resulting from the Working Group's efforts include Louvan E. Nolting and Murray Feshbach, "R&D Employment in the U.S.S.R.," Science, v. 207 (February 1, 1980), pp. 493-503; and Systems for Stimulating the Development of Fundamental Research (Report prepared by the U.S.-U.S.S.R. Working Subgroup on Systems for Stimulating the Development of Fundamental Research of the National Academy of Sciences/National Research Council), NTIS Order Number PB80-162316.

AUTHOR'S ACKNOWLEDGEMENTS

In the preparation of this volume, I wish to acknowledge the contribution by John P. Young, Alvin M. White, Hugh L. Shaffer, and L. Ben Freudenreich, who wrote the initial draft report for Battelle Columbus Laboratories on which this study is based. Although I have added a few new chapters and altered others, I have retained much of the information and insight included in their original analysis. At the same time, I have drawn heavily on other source material, especially the rich and extensive science policy literature that has evolved in the USSR since the late 1960s. In discussing the Kremlin's policy problems and practices, I have also tried, where possible, to cite self-critical Soviet studies in order to illuminate Russian perceptions and problem-solving approaches.

I am deeply indebted to Murray Feshbach, Louvan Nolting, Joseph Berliner, and Herbert Levine for sharing their expertise on the USSR and for offering helpful criticisms, comments, and suggestions. I am equally grateful to the Soviet members of the Science Policy Working Group for the opportunity to interact in this common effort to enhance our mutual knowledge and understanding of the other's system, though we may disagree in our views and conclusions.

My warm thanks also go to my American colleagues on the Working Group for providing me with a tremendous learning experience and "short course" on US R&D planning and management that proved invaluable in preparing the chapter on comparative American and Soviet approaches to S&T policy. Special thanks in this regard are due to Nat Robertson, Bill Carey, and Lowell Steele for their analytical leads and thoughtful advice.

Lastly, I also wish to thank Deborah C. Andrews for editing the manuscript and making it far more readable than it otherwise would have been.

Paul M. Cocks
August 22, 1980

VII BACKGROUND AND APPROACH TO SCIENCE POLICY IN THE USSR

Science policy in the USSR, as in the United States, is significantly shaped by its national context. While American science and engineering reflect the conditions of a competitive market economy and pluralist politics, Soviet R&D takes place against the background of a centrally planned economy and society. The differences between the two countries in science and technology, however, go beyond the differences between capitalism and communism as political ideologies and systems of government. Even before the Bolshevik Revolution in 1917, Russia had a pattern of scientific, educational, and industrial development that was different from that of Western Europe and the United States. The role of the state in running society had always loomed much larger and the autonomy of individuals and institutions was accordingly much more constrained. The evolution of the organizational structure and mechanisms of R&D in the USSR has been a complex process shaped by a mixture of factors. Current policies and practices reflect not only distinctive Soviet influences but also the continuing effects of inherited Russian scientific traditions and patterns. An awareness of these elements of continuity is essential to understanding the nature of R&D planning and management in the USSR today as well as the basic dissimilarities between the Soviet and American approaches.

THE SOVIET COMMITMENT TO SCIENCE AND TECHNOLOGY

No government has been as explicitly committed to science and technical progress as that of the USSR.

The Soviet Union was the first nation to recognize science as a natural resource, to commit systematically large shares of its budget to the promotion of research, and to try to plan the development of science and technology.[1]

Kremlin leaders see their ideology as being synonymous with science, and they have long regarded the latter as an indispensable tool for modernizing Russia. The early Bolsheviks believed that science would "conquer Russia both as a state of mind and as a state of nature."[2] Lenin's definition of Communism as "Soviet power plus electrification of the whole country" captures well the enthusiasm of the times for science and technology during the formative stage of Soviet rule. More than half a century later, Leonid Brezhnev reaffirmed this basic commitment on the 250th Anniversary of the USSR Academy of Sciences. "Socialism and science are indivisible," he emphasized. "Only by relying on the latest achievements of science and technology is it possible to build socialism and communism successfully."[3]

Throughout the period of Soviet rule, Kremlin spokesmen have tended to claim practically unlimited potentialities for science. Indeed, the regime has gone through a long line of technological panaceas upon which, at one time or another, everything was supposed to depend--electrification, mechanization, chemicalization, etc. Today the "technological fix" appears to be centered on computerization and automation. This almost eternally optimistic attitude of the government and society toward science as a progressive force of great untapped potential reflects the scientific optimism to which Marxism was heir. In fact, a defense of science in 18th century enlightenment terms, Loren Graham observes, is probably more popular today among intellectuals in the Soviet Union than in Western states, where the appeal of this model has diminished. Moreover, the USSR Academy of Sciences is the only one of the 18th century European academies of sciences which still dominates the science of its nation.[4]

The importance attached to scientific and technical progress in Soviet ideology has encouraged the acceptance of large expenditures on R&D, especially in the postwar period. The rate of growth of expenditures on science for the past 25 years, in fact, has outstripped the rate of increase of both national income and industrial production. Unlike the United States, there has been no "flight from science" during the past decade. While allocations for R&D rose in the US to 2.5 percent of the GNP in 1965 and have fallen ever since, official expenditures on science as a portion of national income have risen in the Soviet Union from 1.3 percent in 1950, to 2.7 percent in 1960, to 4.8 percent in 1975.[5] If we add development activity at the enterprise level, which is not included in "official" science figures, then the total share of national income has probably been about 7 or 8 percent throughout the 1970s. While official allocations for science have tended to stabilize in recent years at around 5 percent of the national income, this rate is still significantly higher than that of any nation in the Western world.

At the same time, certain tensions and conflicts between science and ideology impede scientific and technological developments. The commitment to science is "conditional." The Soviet government, like its Tsarist predecessor, has been ambivalent toward science. On the one hand, it sees science as indispensable for economic modernization and for enhancing Soviet military power; on the other hand, the regime distrusts the scientific spirit with its critical attitude towards authority and individualistic approach to problem-solving. The evolution of science as an autonomous social activity carries the dangers of professional exclusiveness, elitism, and the assertion of rationalistic modes of thought. Manifestations of dissent in recent years among scientists testify to the reality of these dangers and make ideological problems a continuing basic concern of Soviet science policy.[6] Dzherman Gvishiani, a deputy chairman of the USSR State Committee for Science and Technology, emphasizes that "all socialist states cannot but grant great significance to the mastering by scientists of Marxist-Leninist methodology, and to the struggle against manifestations of bourgeois ideology and bourgeois objectivism and subjectivism."[7]

Political and ideological constraints have varied over time, however. Under Stalin, control extended to scientific theory itself, and particular interpretations of theory were forced upon scientists. As a result some scientific fields, like biology and cybernetics, were deliberately suppressed or retarded. The social sciences in particular have suffered from the encounter with ideology. While the boundaries of intellectual freedom to pursue research have been extended in the post-Stalin period, science has not been freed from political influence. Soviet authorities still make demands upon the scientists, although frequently different ones than they made in the past. Controls over scientists have not really been relaxed, but the goals of such controls have been redefined in accord with changing official perceptions of national needs. Today it is the problems of a more sophisticated society and industrial order than those of the steel age of industrial expansion that Soviet scientists and engineers are under pressure to address and solve.[8]

CENTRALIZATION OF R&D PLANNING AND MANAGEMENT

The conduct of scientific research and development in the USSR is subordinate, at least in principle and aspiration, to strong central planning and management. R&D shares this characteristic with other broad areas of economic and social activity in a system wherein the vast majority of the means of production is owned and managed by the state. Accordingly, it is impossible to distinguish between purely governmental or public and purely industrial or private sectors. Rather, there is simply one giant public sector. At no point in R&D decision making is there an apparent juncture of the kind visible in the American pluralistic setting when government policy impacts on thousands of semi-independent private decision makers. Rather, the transition in the Soviet Union from central policy to individual decisions follows a continuum.

Given the particular shape and ethos of the system the claim is frequently made in Moscow that Kremlin leaders are able to pursue a comprehensive and coherent national science and technology policy, and this is the image of Soviet policy that generally exists abroad. It contrasts sharply with the situation in the United States where there is no formal, broadly based, and unified policy for R&D (especially outside of defense and space) but rather a confusing mixture of policies, a diffusion of responsibility, and a fragmentation of administration.

At the outset, however, it is important to emphasize that this popular Western image of a tightly centralized and coordinated Soviet S&T effort has never corresponded with reality. Central planning and management of R&D is still highly imperfect. S&T planning has always been much more rudimentary than economic planning. Although much more centralized and comprehensive than the American system, the Soviet approach is far from the holistic model that it is sometimes portrayed to be. The Kremlin's reach in science policy continues to exceed its grasp. Aspirations outdistance capabilities. There are still many holes in the whole. The interplay of multiple agencies with diverse perspectives, different wills, and competing interests continues to constrain the actions and to limit the capabilities of central authorities to formulate and implement coherent policies in science and technology.

To be sure, the idea of central planning of science was established early in the life of the Soviet regime. Centralization of R&D was regarded not only as a means of eliminating the duplication of effort and secrecy that were characteristic of capitalist states but also of making the most effective use of Russia's scarce S&T resources. Tradition as well as ideology fed the propensity for central planning. Throughout Russian history, science and education, with only a few exceptions, had been subject to central, state control. Private initiative was resented by the rulers of imperial Russia in any field, including science and learning. In any case, the Soviet Union became in the 1920s the first nation in history to attempt to formulate a policy towards science and technology as a whole. It began conducting statistical and organizational surveys of scientific personnel and institutions a decade before other countries, including the United States.[9]

Despite all the talk about science planning and policy during the twenties, however, little action was actually taken in this direction. The first national conference on planning of scientific research did not meet until 1931. A member of the Communist Party was not elected to the Academy of Sciences until 1929, and only in the thirties did the scientific affairs of the Academy begin to reflect Party desires. Actually, the innovative posture of the government in this policy sphere in the 1920s gave way to a sterile approach under Stalin. From the early 1930s until Stalin's death little was done about the formulation of science policy and the planning of science. Though research organizations, like all Soviet institutions, drew up annual plans, these were not meaningful. Serious attention began to be given to the planning and management of R&D only after the mid-1950s.[10] By then, the USSR, the initial pioneer in national science planning, lagged behind a number of Western industrial nations in this area.[11]

Similarly, the search for one central coordinating agency to oversee the development of science and technology was gradually abandoned by the mid-1930s. No Commissariat of Science was ever created. Instead, responsibility for R&D planning and management rested for the next 20 years primarily with the industrial commissariats and later ministries as well as several central departments. Much like the American pattern, the Soviet R&D effort was structurally and administratively fragmented among multiple mission-oriented agencies with conflicting jurisdictions and interests. Though formal control existed at the all-Union level, there was no effective coordination of policy at the center. Basically, there were four main organizational actors in science and technology policy: the USSR Academy of Sciences, the State Planning Committee, the industrial commissariats or ministries, and the commissariats or ministries of education. Of these four the most important was the Academy. While industrial R&D was formally coordinated by the State Planning Committee, each ministry in reality looked after its own research needs until 1957 when the ministerial system was substantially reorganized.[12]

Thus, national science planning and policy as such is as much a postwar phenomenon in the USSR as it is in the United States. The development of science and technology began to be planned on a general state basis rather than on the level of separate institutions only in 1949, when an annual plan for the introduction of new technology was formulated for the first time.[13] Only in 1956, however, did the plans begin to include assignments for scientific research. Sections on the financing of research and on the provision of materials and equipment were not added to the plans for science and technology until 1962. Also at this time plans for training scientific manpower began to be compiled. In 1967, for the first time, targets for the application of computer technology and management information systems were included in the annual plan for S&T. The following year the All-Union Scientific and Technical Information Center began recording all research projects in the country. Efforts to develop a comprehensive plan for nationwide technical standards did not start until 1971. The state registration of all experimental design projects did not begin until 1973.

Moreover, the planning of science remained confined to a one year time frame until the mid-1960s. In 1966, for the first time, a list of 250-odd priority R&D problems was drawn up and included in the five year macroeconomic development plan. Only toward the end of the 1960s did systematic long-range (10/15 years) studies begin to be organized in scientific forecasting and technology assessment on the development of industrial branches and on national problems such as the future fuel and energy balance, development of the transport system, the use of metal and lumber, and the provision of an adequate food supply. Work on a "Comprehensive Development Program for Science and Technology and Its Social and Economic Consequences" up to 1990 started in 1972, and a draft of this program was largely completed by the fall of 1975. The issue of ecological development has only recently become an object of central planning. Thus the current Tenth Five Year Plan (1976-1980) includes for the first time a separate chapter on the rational utilization of natural resources and environmental protection.

Organizationally, too, the first real step towards an overall coordination of R&D was taken only in 1961 with the creation of the State Committee for Coordination of Scientific Research. In 1965 this body was reorganized into the present State Committee for Science and Technology. Taken together, then, all these measures give substance to the statement by Gvishiani in early 1972 that "the various forms of state activity in the sphere of science are, on the whole, still in the formative stage. While some of them have been applied for decades, others have emerged relatively recently."[14]

Inspite of some advances, however, the Soviet S&T establishment remains highly deficient as a model of effective systems planning, management, and control. Research and development continues to be housed in a myriad of institutions and fenced off by strong departmental barriers that slow and impede the innovation process. Efforts to strengthen integrating structures and functions have met with only partial success. The whole system still bears the heavy chalk marks left by the branch ministries and central agencies which participate in and share responsibility for science policy.

It is important to stress that Kremlin authorities have not abandoned their basically centralized approach and holistic perspective toward science policy, even in face of the growing size and complexity of their R&D effort. On the contrary, a perceived need to accelerate science and technology has led them to press all the more strongly in the 1970s for new techniques of systems planning and management. Their commitment to central planning remains firm. "The scale and complexity of these problems," says Gvishiani, "are such that in present-day conditions they can be tackled only on the level of state policy."[15]

Today, modern systems technology and terminology have become the fashion of the times in Soviet discussions of science policy. The new systems movement and management mentality are very much in keeping with the conventional centralized approach to science policy. At the same time, however, the new systems rhetoric continues to suggest an image of unity, coherence, and wholeness that are still lacking in reality.

THE SEPARATION OF SCIENCE AND INDUSTRY

Science and industry in the USSR have always been largely separate worlds, more coexisting apart than mutually cooperating and pulling in the same direction. They are, to use Pravda's recent imagery, like "two flagships proceeding on different courses, in different seas."[16] Or, to phrase the analogy slightly differently, they often appear like two ships "passing in the night," unaware of the other's presence and activity. This basic and persistent feature of the system forms an essential background to an understanding of the Soviet situation, especially the serious interface problems involved in technological development and delivery.

On the one hand, a bias in favor of theoretical work pervades the world of scientific research and development. Lacking usually their own experimental facilities and generally neither rewarded nor penalized for the success or failure of their results, research scientists and design engineers tend to do their work with little reference to its practical application. Development work does not usually hold the excitement and drama of fundamental research, particularly in the civilian sector. Soviet higher educational establishments offer practically no specialization for designers and technologists. The notion that "small is beautiful" remains overshadowed by an infatuation with "big science" and "big technology."

Historically, too, Russian science has been known for its strong theoretical orientation. Its greatest figures were theoreticians, such as M. Lomonosov and D. I. Mendeleyev in chemistry, P. N. Lebedev in physics, and N. I. Lobachevsky and P. L. Chebyshev in mathematics. In contrast to American culture little place or prestige was given to the practical tinkerer and innovator, much less the technological entrepreneur. The Imperial Academy of Sciences, from the time of its foundation in 1725, was primarily theoretical in orientation and relatively isolated from industry. The continuing predominance of the Academy as the organizational center of Soviet science assures the theoretical bias of the national scientific tradition. In general, both pre- and post-revolutionary scientific R&D have not affected contemporary economic life significantly.[17]

Since the earliest days of Soviet rule efforts have been made to bring science closer to practical matters and social concerns. Scientists have been constantly instructed to serve socialism and to help solve problems facing society and the economy. The R&D establishment has been repeatedly reorganized to achieve a better coupling between research and production. Nonetheless, the translation of scientific ideas into use remains a major problem to this day. The bias of the official ideology and of the regime for applied science and technology still acts as an ineffective corrective to older entrenched scientific traditions.

Industry, on the other hand, has traditionally had a strong production bias and discriminates against new technology "like the devil shies away from holy water," to use Brezhnev's words.[18] The short time horizon of planning, the general low quality of preproduction work, the absence of adequate in-house R&D services, and all the uncertainties surrounding material supply and financing for new technology tend to make enterprise managers concentrate on current production operations and minimize the rate of innovation. Given the balance of relative risks and rewards, they find it more advantageous to expand existing production lines than to establish new products and processes. In short, the present invariably drives out the future.[19]

The weakness of applied R&D can also be traced to historical and structural factors. Industrial research was largely lacking in prerevolutionary Russia, which derived much of its technology and industrial capital from the West. The Soviet regime decided early to organize and promote applied scientific R&D in specialized institutes subordinate directly to the industrial commissariats. The creation of such large, central institutes serving particular branches of Soviet industry as a whole rather than individual plants, it was believed, would build a more effective industrial research establishment than in capitalist states where R&D was fragmented among numerous firms which competed with each other and concealed their innovations if possible.[20]

Since the mid-1960s this pattern of insulating R&D from the normal economic processes has been subject to mounting criticism. Although the separation of science from production was once seen as playing a positive role in allowing the USSR to develop a strong and autonomous research sector unfettered by excessive industrial claims and demands, it is now perceived as contradicting the interests of both science and production.[21] Today, science, technology, and production are said to be increasingly interacting and interdependent processes that develop not in isolation and by themselves but through their linkage with one another. The coupling processes must accordingly be organized "so as to achieve a fast and effective flow of scientific and technological ideas into industry and an equally fast and effective counterflow of orders from industry to science." Only by building better structural crosslinks can production be made "to soak up new scientific ideas like a sponge."[22] While the interactions between science and industry have indeed become more direct and complicated in recent years, organizational and motivational bonds have not yet been formed that are capable of breaking down the barriers separating these two worlds.

The strong military orientation of scientific R&D, along with the secrecy that surrounds it, has contributed to the underdevelopment of industrial technology. Much like the United States, the Soviet regime has spent enormous sums on defense, aerospace, and nuclear R&D while underinvesting in industrial R&D. Nor has there been any substantial spin-off from these national security and high technology related projects in terms of civilian applications to national needs and improvements in the quality of life. The resulting pattern has been a high concentration of talent and money in defense and space and a seriously distorted deployment of S&T resources. This pattern is not new to the Kremlin. A preoccupation with defense technology and the political-military orientation of the state-directed effort are deeply rooted in Russian history. From the time of Peter the Great Tsarist governments were interested in applying technology largely to military purposes.

Still another thread of continuity in the Russian/Soviet complex of science and technology deserves mention: the role of external influences in Russia's development. Throughout its history, Russia's scientific and technical ties with foreign countries, especially the Western world, have been limited and intermittent, if at times quite energetic. Internal regime attitudes, Tsarist and Soviet, have fluctuated between two extremes. At times the government resorted to artificial and imposed isolation. At other times, it actively sought international cooperation and exchange. Since Russian science was traditionally in advance of Russian technology, the breakdown of foreign contacts tended to intensify, in particular, Russia's technological lag.[23] Consequently, the government would periodically rely upon heavy doses of imported foreign technology to strengthen its military power and to help overcome Russia's economic and technological backwardness. From this perspective, Moscow's intensified efforts in the 1970s to expand scientific cooperation and technology transfer, especially with the nations of Western Europe and the United States, should be seen as part of an older tradition and development strategy.

TWO SYSTEMS FOR GUIDING TECHNICAL PROGRESS

As a result of the particular course followed by the Soviet Union in science, technology, and economic growth essentially two systems have evolved for guiding technical progress. The primary line of influence is the basic economic system. This structure was created in the prewar years and evolved in response to the demands of rapid industrialization. Science and technology did not provide the principal motive force for its operation. Bearing a strong anti-innovation bias, this system remains fundamentally oriented to the expansion of existing patterns of production and technology. A secondary line of influence is exercised by a special set of structures and mechanisms which began to take shape around the mid-1950s with the burgeoning growth of the Soviet R&D effort. This supplementary system attends to the problems of science and technology policy and performance. Acceleration of the rate of innovation is one of its main goals. Each system has its own plans, budgetary practices, incentive schemes, and integrating administrative organs. Typically, however, there is lack of coordination between the basic and supplementary systems. Indeed, they frequently work at cross purposes to each other.

In general, the focus of Soviet S&T policy in the 1970s centered largely on how to improve these two guidance systems. As regards the supplementary machinery, some elements are still lacking. Among them are effective procedures and organizational solutions for creating and applying new technology that involves the joint cooperation of multiple ministries and agencies. Second, some elements of the supplementary system, such as the policy of pricing new technology, need to be improved. Third, the separate parts of this system are not well coordinated. Finally, the supplementary system for scientific research, development, and innovation needs to be better integrated with the general system of economic planning and management. Controversies abound over how to solve these problems.[24] As yet, no grand systems solution has been found, though the search goes on. We can be sure, then, that these issues will continue to occupy a prominent place on the Kremlin's S&T agenda for the 1980s (see chapter 12).

In sum, these are some of the basic features and underlying traditions of the contemporary science and technology establishment in the USSR. An awareness of them adds to our understanding of particular Soviet patterns and problems of organizing, planning, and managing R&D, which are discussed in more detail in the following pages.

FOOTNOTES

1. Loren R. Graham, "The Development of Science Policy in the Soviet Union," in T. Dixon Long and Christopher Wright, eds., Science Policies in Industrial Nations (New York: Praeger Publishers, 1975), p. 13.

2. Ibid., p. 19.

3. Pravda, October 8, 1975.

4. Loren Graham, "The Place of the Academy of Sciences in the Overall Organization of Soviet Science," in John R. Thomas and Ursula M. Kruse-Vaucienne, eds., Soviet Science and Technology: Domestic and Foreign Perspectives (Washington, D.C.: George Washington University, 1977), pp. 44, 56. See also Raymond Hutchings, Soviet Science, Technology, Design: Interaction and Convergence (London and New York: Oxford University Press, 1976), pp. 116-119.

5. E. I. Valuev, L. S. Glyazer, V. P. Groshev, V. I. Kushlin, M. P. Kokonina, G. A. Lakhtin, V. G. Lebedev, Yu. K. Petrov, S. V. Pirogov, and S. M. Ryumin, "Osobennosti finansirovaniya nauki v SSSR (Unique Characteristics of the Financing of Science in the USSR)" (Moscow, December 1976), p. 7. Report prepared for the US-USSR Joint Working Group in the Field of Science Policy, Subgroup IV: Financing of Research and Development.

6. See Julian N. Cooper, "The Organization and Planning of Research and Development in the USSR," Paper prepared for the Conference on Technology and Communist Culture, Bellagio, Italy, August 22-28, 1975. See also Alexander Vucinich, Science in Russian Culture, 1861-1917 (Stanford, California: Stanford University Press, 1970), p. xi.

7. D. M. Gvishiani and A. A. Zvorykin, eds., Osnovnyye printsipy i obshchiye problemy upravleniya naukoi (Moscow: Nauka, 1973), p. 39.

8. Graham, "The Development of Science Policy in the Soviet Union," pp. 38-41.

9. Ibid., pp. 12-13, 22-23.

10. Ibid., pp. 23-24, 27-29.

11. E. Zaleski, J. P. Kozlowski, H. Wiennert, R. W. Davies, M. J. Berry, and R. Amann, *Science Policy in USSR* (Paris: Organization for Economic Cooperation and Development, 1969), p. 25.

12. Graham, "The Development of Science Policy in the Soviet Union," pp. 29-30.

13. Prior to this time, the USSR and republic state planning committees and the USSR and republic academies of sciences did little more than tabulate research plans submitted by performing institutions. They made no effort to pass on priorities, to coordinate the plans and to eliminate duplication, or to link them to national and branch plans for industrial production and capital investment. Before 1949 no consolidated plan sections for R&D existed in the general annual and five year plans for development of the national economy. Though expansion of production facilities entailed planning new technology, most of the technology was acquired from abroad and the planning was submerged in the production plans of branches and enterprises. See Louvan E. Nolting, *The Planning of Research, Development, and Innovation in U.S.S.R*, U.S. Department of Commerce, Foreign Economic Reports, No.14 (Washington, D.C., 1978), p. 7.

14. D. M. Gvishiani, "Centralized Management of Science: Advantages and Problems," *Impact of Science on Society*, XXII (January-June 1972), p. 97.

15. D. Gvishiani, "The Scientific and Technological Revolution and Scientific Problems," *Social Sciences* (Moscow), I (7) (1972), p. 47.

16. *Pravda*, July 3, 1977.

17. Hutchings, Soviet Science, Technology, Design, pp. 4-5. See also Ronald Amann, "The Soviet Research and Development System: The Pressures of Academic tradition and Rapid Industrialization," Minerva, VIII (1970), pp. 221-224.

18. Pravda, March 31, 1971.

19. For the best discussion of the problems of innovation, see Joseph Berliner, The Innovation Decision in Soviet Industry (Cambridge, Massachusetts: MIT Press, 1976).

20. Graham, "The Development of Science Policy in the Soviet Union," pp. 25-27. See also his excellent essay, "The Formation of Soviet Research Institutes: A Combination of Revolutionary Innovation and International Borrowing," Social Studies of Science, No. 5 (1975), pp. 303-329.

21. L. S. Blyakhman and A. F. Ivanov, "Nauchno-proizvodstvennoye obedineniye kak forma sistemnoi organizatsii tsikla issledovaniye-proizvodstvo," Izvestiya Akademii nauk SSSR, seriya ekonomicheskaya, 6 (1971), p. 39.

22. V. G. Afanasyev, Nauchno-tekhnicheskaya revolyutsiya, upravleniye, obrazovaniye (Moscow: Politizdat, 1972), pp. 26-27, 312-313.

23. See the discussion by Hutchings, Soviet Science, Technology, Design, pp. 9-11 and the three volume study by Anthony C. Sutton, Western Technology and Soviet Economic Development, 1930-1965 (Stanford: Hoover Institution Press, 1971-1973).

24. On these two guidance systems, see G. Kh. Popov, Effektivnoye upravleniye (Moscow: Ekonomika, 1976), pp. 128-136.

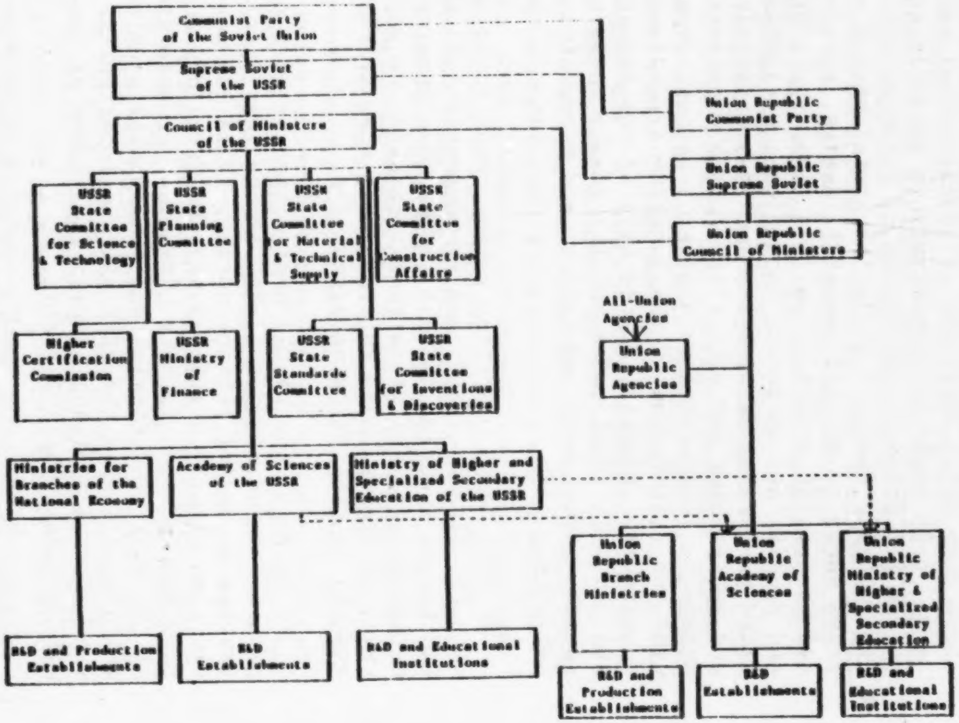
VIII THE ORGANIZATION OF R&D

OVERALL STRUCTURE AND INSTITUTIONAL SETTING

In keeping with the Kremlin's basically centralized approach to science policy, the organization and conduct of R&D in the USSR are highly structured along strong hierarchical lines. Soviet authorities attempt to plan and manage the research-to-production process as a single unit. Accordingly, the institutional structure that has been created to promote the process is regarded as an integrated "organizational system" with relatively detailed formal roles and responsibilities assigned to the vast array of individual actors and special agencies that make up its constituent parts.

Generally speaking, as many observers have noted, the overall institutional framework resembles the internal organization of a large business enterprise that operates on mainly three levels (Figure 9-1). At the top or apex of the pyramid is the corporate "headquarters" that includes the chief executives and their main staff assistants and offices. Their task is to develop broad strategy and to set organizational policy and procedure. In the USSR the central decision making authorities include both Communist Party and governmental units at the all-union or national level as well as the republic level. There are also what we may term "functional" agencies which are responsible for the formulation, coordination, and monitoring of policy in a given area for all establishments in the economy. Most of these agencies are designated "state committees" and report directly to the central governmental policy-making organs. Such functions as planning, finance, and supply are the responsibility of bodies of this type.

FIGURE 8-1 OVERALL STRUCTURE OF THE SOVIET SYSTEM OF R&D PLANNING AND MANAGEMENT


Communist Party of the Soviet Union
Supreme Soviet of the USSR
Council of Ministers of the USSR
USSR State Committee for Science & Technology
USSR State Planning Committee
USSR State Committee for Material & Technical Supply
USSR State Committee for Construction Affairs
Higher Certification Commission
USSR Ministry of Finance
USSR State Standards Committee
USSR State Committee for Inventions & Discoveries
Ministries for Branches of the National Economy
Academy of Sciences of the USSR
Ministry of Higher and Specialized Secondary Education of the USSR
R&D and Production Establishments
R&D Establishments
R&D and Educational Institutions
Union Republic Communist Party
Union Republic Supreme Soviet
Union Republic Council of Ministers
All-Union Agencies
Union Republic Agencies
Union Republic Branch Ministries
Union Republic Academy of Sciences
Union Republic Ministry of Higher & Specialized Secondary Education
R&D and Production Establishments
R&D Establishments
R&D and Educational Institutions

Below this top governing structure, on a second level, are the specialized and relatively autonomous "product" divisions and "line" agencies which are responsible for directing all activities of a collection of performing establishments which operate in a particular area. In the Soviet context there are three such major divisions or institutional subsystems. Each tends to concentrate on specific stages of the R&D process. Academies of sciences specialize in basic research while industrial branch ministries focus on applied research, design, development, and production assimilation. The Ministry of Higher and Specialized Secondary Education constitutes the third performing network and includes universities and independent R&D facilities. Such organizations engage in fundamental or applied research, depending upon the orientation of the facility or individual researcher. Finally, at the base of the structure are the individual units which actually conduct research, development, education, and production activities.

At each level operating policy tends to be set with the direct or indirect participation of the functional agencies in their respective domains. The nature and role(s) of pertinent specific or generic types of organs noted in Figure 9-1 are described briefly in the following discussion.

To be sure, the highly centralized pattern of organization and conduct of R&D is the most distinctive feature of Soviet science policy. This characteristic also clearly distinguishes the Kremlin's approach from the American format. However, our understanding of the basic functioning and fundamental problems of scientific R&D in the USSR will be imperfect if we see only the dominant hierarchical lines of the formal organizational blueprint.

Though strongly centralized, the Soviet system is far from being a monolith. The institutional world of R&D is, indeed, a highly complex and compartmentalized structure. Power is dispersed and authority is divided among a myriad of organizational centers.

In 1972, for example, nearly 140 ministries on either an all-union or union republic level had under their jurisdiction R&D establishments.[1] This fragmented administrative structure, in turn, influences--if not dictates--the fundamentally bureaucratic character of science policy making and implementation. Adhering to the principle that "science cannot be administered exclusively from a single center," Kremlin authorities emphasize the joint realization of planning and management functions.[2] That is, the basic _modus operandi_ in Soviet R&D revolves around joint decision making, power sharing, and cooperative actions in a multi-organizational context.

To a large extent, the overall structure itself generates certain "pluralist" forces and tendencies in Soviet R&D. Though admittedly of a different kind and degree than in America, organizational pluralism exists and exerts substantial influence on the policy process. The research-to-production cycle must pass through a variety of decision paths and clearance points. Disagreements and delays over choices and strategies occur at every turn. Cooperation is achieved and maintained with great difficulty. Nothing works smoothly. Given this context, a heavy burden falls particularly on those agencies responsible for coordinating R&D. As the principal referees and synthesizers, they are the ones who must develop and display effective managerial abilities in balancing mixed coalitions of opinion, criticism, and advocacy in the pursuit of national goals.

While these behavioral features of Soviet R&D planning and management are treated in more detail in subsequent chapters, we mention them here because they are largely rooted in and shaped by organizational factors. Moreover, structure _per se_ is inherently static. In any brief description of formal infrastructure it is easy to lose sight of the organizational dynamics around which the whole machinery turns.

It is also important to note that the Soviet S&T establishment has evolved over several decades. There is no evidence that the distribution of power among the central agencies concerned with administering R&D has changed significantly during the last 10 years. At the performing level, on the other hand, considerable experimentation and some change have taken place in the organization of R&D in this interval. In general, though, institutional continuity and stability have been distinct hallmarks of Soviet science and technology.

At the same time, science analysts and political leaders in Moscow have begun increasingly to take a second look at basic organizational approaches in response to complaints that R&D institutions suffer from too much stability, that they have become structurally rigid and unresponsive to changing conditions and new demands. Subsequently, some efforts are underway to create new, or at least modified, institutional arrangements and more effective organizational forms linking and integrating the innovation process. We return to a discussion of these contemporary organizational issues in the final part of this study.

For the moment, our task is to present the formal organizational chart and to outline the main entities managing and supporting Soviet research and development. This panoramic sketch helps orient subsequent discussions of the formulation and implementation of R&D plans. The latter, in turn, provide explanations of the terminology employed in the brief descriptions of the roles of the participating organizations.

THE TOP GOVERNING MACHINERY

All threads of decision making in science policy, as in other major issue areas, come together at the peak of the Soviet political pyramid. Though power tends to be highly concentrated, there is, even at the top, structural and functional differentiation, which is reflected in separate institutions charged with executive, legislative, and administrative functions. Thus, the organization of authority continues to take the form of an intricate, weblike structure of specialized agencies, divided responsibilities, and complex relationships.

Central Policy-Making Organs At the All-Union and Republic Levels

Policy-making authority is formally exercised by three organs at the all-union and republic levels. These are (1) the leadership elements of the Communist Party, at the all-union level the Central Committee and its elected Politburo and Secretariat; (2) the legislative organ, at the all-union level the Supreme Soviet; and (3) the Councils of Ministers. The authority wielded by the Party derives from its status as the only ruling party and sole repository of legitimacy in the system rather than from any formal responsibility within the Soviet governmental hierarchy. The highest organ of state authority, as specified in the Soviet constitution, is the Supreme Soviet, while the USSR Council of Ministers, reporting to the Supreme Soviet, is the central administrative organ of the government. There are counterpart bodies for the Supreme Soviet, the Council of Ministers, and the Central Committee of the Party in each of the 15 republics of the Union* with the exception of the Russian Soviet Federated Socialist Republic, where there is no republic Central Committee.

This general tripartite division of institutions and functions, however, should not be taken to imply a genuine separation of powers or checks and balances along American lines. In actuality, it has always been clear that final authority in the USSR rests with the Communist Party and its own executive apparatus. The legislative and executive branches of government are of secondary importance in the formulation of fundamental policy, and, sometimes, in deciding even operational questions. Though a more rational division of decision making responsibility has recently evolved, the real political bargaining over basic policy still occurs within the executive organs of the Communist Party.

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*These are the Russian, Estonian, Latvian, Lithuanian, Belorussian, Ukrainian, Moldavian, Armenian, Georgian, Azerbaidzhan, Kazakh, Turkmen, Tadzhik, Uzbek, and Kirgiz Soviet Socialist Republics.

The Communist Party of the Soviet Union (CPSU)

Although the Party has no formal responsibility in R&D planning and management, the de facto authority of the Party is extensive. The highest organs of the Party--the Politburo and the Secretariat--generally are acknowledged to be, respectively, the leading decision-making body and chief executive arm in the Soviet Union. The Politburo defines national priorities and determines the broad contours of policy for the economy, science, and technology. Directives of the Politburo, in turn, are reflected in the policy deliberations and formulations of the USSR Council of Ministers; indeed, questions of fundamental importance are decided jointly by the Central Committee and the Council and are published as joint decrees. As evidence of the close working relationship between the Party and government leadership elements, virtually all members of the USSR Council of Ministers are also members of the Central Committee and, in some cases, also of the Politburo.

The Central Committee Secretariat is the chief executive body of the Party charged with operational coordination and day-to-day decision making. The Secretariat reserves the right to intervene in the workings of the ministries and other government agencies to enforce priorities. Its Department of Science and Higher Educational Institutions exercises broad oversight responsibilities in science-related matters. In addition, this department has been a major training ground for high level science and educational administrators. For example, M. A. Prokofiev, the Minister of Education, was at one time its head as was V. A. Kirillin, the Chairman of the State Committee for Science and Technology. Other departments of the Secretariat that appear to play important roles in S&T policy are those of Defense Industry, Heavy

Industry, Chemical Industry, and Planning and Finance. In general, though, our knowledge of the nature and distribution of functions within the apparatus of the Central Committee in this policy sphere is very limited.

It is clear that considerable influence is exercised by the Party machinery through its general control of personnel selection. All major appointments in scientific and educational institutions are first screened and approved by the Central Committee or its local counterparts, depending upon the significance of the post.

Below the level of the Central Committee, Party organization to a large degree parallels the organization of the government and economy. Party organs are established on a territorial basis (republic; province, and city). Party cells or at least representatives are also created in all significant performing establishments. Down the hierarchies of public administration, Party officials supervise and penetrate the legislative and executive organs of government, in a complex pattern of cooptation and interdependence. A principal reason for this kind of organizational arrangement is to enable Party authorities to monitor economic and technical planning and performance through channels independent of the government hierarchy and, when necessary, to facilitate plan fulfillment with such measures as Party assistance in resource allocation.

In general, Party organs have a pronounced impact on science policy formulation and implementation, particularly at the highest levels of the Party. While the informal or unstated nature of the impact renders it difficult to document systematically, the Party remains a potent force.

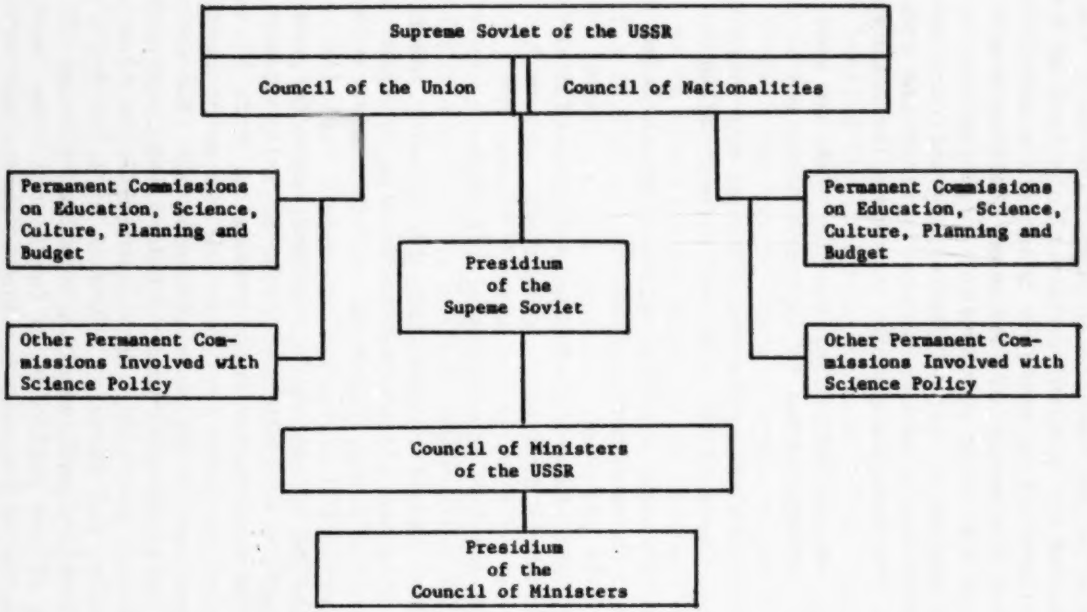
The Supreme Soviet of the USSR

The Supreme Soviet is the highest legislative body in the Soviet government. About 1500 deputies are elected to this "parliament," usually every five years, from among the "leading elements" of Soviet society. As a general estimate, about 35 percent of the deputies are "outstanding" workers and peasants by occupation, 35 percent are Party officials and government administrators, and the remainder are various kinds of professionals, including scientists and engineers. Though membership in the Communist Party is not required for election, about three quarters of the deputies elected to the Supreme Soviet in 1974 were Party members. The internal organization of the Supreme Soviet and the relationship of the Soviet to the Council of Ministers is illustrated in Figure 9-2.

The Supreme Soviet generally meets in full session no more than six to seven days a year. During these sessions the deputies briefly discuss and approve legislation formulated and presented by the Council of Ministers and the Party Central Committee. Between meetings, the authority of the Supreme Soviet is exercised by its Presidium. This body includes 39 members: a chairman, a first deputy chairman, 15 deputy chairmen (comprised of the chairmen of the supreme soviets of the 15 union republics), a secretary, and 21 ordinary members. Of the latter group elected to the Presidium in 1974, 11, including Brezhnev and 5 other members of the Politburo and Secretariat, were members or candidates of the CPSU Central Committee. The composition of the membership again shows the interlocking character of Party and government authorities at the top of the political command structure. The Chairman of the Supreme Soviet Presidium, it may be noted, is referred to as the president of the USSR. In June 1977 Leonid Brezhnev assumed this post in addition to his position as General Secretary of the Party.

In general, the Supreme Soviet has great constitutional authority but little effective political power. While the Soviet is officially the head of the government, the sessions of the Soviet are too short to permit meaningful deliberation of policy. Its primary concern is to legitimize and propagandize policies made elsewhere.

FIGURE 8-2 TOP LEVEL GOVERNMENTAL ORGANIZATIONS RESPONSIBLE FOR SCIENCE POLICY MAKING IN THE USSR


Supreme Soviet of the USSR
Council of the Union
Council of Nationalities
Permanent Commissions on Education, Science, Culture, Planning and Budget
Other Permanent Commissions Involved with Science Policy
Presidium of the Supeme Soviet
Permanent Commissions on Education, Science, Culture, Planning and Budget
Other Permanent Commissions Involved with Science Policy
Council of Ministers of the USSR
Presidium of the Council of Ministers

Source: "USSR Short Answers to US Questions Relating to USSR Research and Development Planning and Management," p. 13.

The *de jure* functions of the Supreme Soviet relating to R&D planning and management include discussion and approval of national plans and of legislation regarding the organization of state administration of science and technology. Overall, the involvement--if not influence--of the Supreme Soviet in policy making may have increased somewhat in 1966 with the creation of permanent standing commissions for such matters as education, science, and culture; planning and budget; industry; agriculture; and transportation and communications. These commissions have the formal authority to do the following:

1. Supervise activities of organs of state administration in appropriate fields
2. Make preliminary studies of appropriate sections of the national economic plan
3. Present findings on matters submitted for their consideration
4. Initiate legislation and present it to the full Soviet[3]

The Council of Ministers of the USSR

The Council of Ministers is the most powerful organ of state administration and the final authority on the organization of Soviet ministries. Composed of nearly 100 members, the Council includes the heads of the most important government agencies, and *ex officio*, the 15 chairmen of the councils of ministers of the constituent union republics. With the exception of the latter group, each member of the Council is responsible for administering specific sectors of the nation's economic, political, military, or social-cultural life. His administrative domain may include, for example, a branch of industry; a national level or interrepublic service, such as the running of the railroads; a functional area, such as planning or finance; or such agencies as the Ministries of Foreign Trade, Education, and Justice.

Ministries are basically of three kinds: all-union, union-republic, and republic. All-union ministries are established for sectors of national importance and priority with no clear republic orientation; examples are the chemical and aviation industries. These ministries, which are highly centralized in Moscow, directly administer activities and facilities under their jurisdiction, regardless of their geographical location. Union-republic ministries are established for sectors where there is significant intrarepublic activity. Union-republic ministries may administer a few activities directly, but they ordinarily operate through counterpart ministries bearing the same name in each of the republics. Thus the USSR Ministry of Health transmits its directives for implementation by the ministries of health in each republic. Legally, union-republic ministries in the republic are responsible to the republic councils of ministers and legislative organs as well as to their parent ministry in Moscow. Examples of union-republic ministries with counterpart ministries in all republics are Agriculture, Construction Materials, and Culture. Examples with ministries in only selected republics are the Coal Industry and Ferrous Metallurgy. Republic ministries, the third type, generally are concerned with services, such as automotive transport or local industry. Republic ministries are not represented in the USSR Council of Ministers, but operate under the immediate supervision of the councils of ministers and legislative organs of the individual republics.

Chairmen of state committees sit on the USSR Council of Ministers and are accorded the same status as ministers. State committees deal primarily with matters that cut across the jurisdictions of conventional departments. Those prominent state committees, which significantly influence the development of science and technology, include:

1. The State Planning Committee (Gosplan)

2. The State Committee for Science and Technology (GKNT)

3. The State Committee for Material and Technical Supply (Gossnab)
4. The State Committee for Construction Affairs (Gosstroy)
5. The State Committee for Inventions and Discoveries (Goskomizobreteniya)
6. The State Committee for Standards (Gosstandart)
7. The State Bank (Gosbank)
8. The Central Statistical Administration (TsSU)

Other minor agencies of the Council whose activities relate to science and technology are:

1. The State Committee for Utilization of Atomic Energy
2. The Main Administration for Geodesy and Cartography
3. The State Committee on Hydrometeorology and Environment
4. The Main Administration of Microbiological Industry
5. The Committee for Lenin and State Prizes in Science and Technology

Given the unwieldy size of the Council of Ministers, cohesion and coordination are provided by its Presidium, a kind of inner cabinet. The Presidium includes the chairman, two first deputy chairmen, and about 10 deputy chairmen. Among the deputy chairmen are the heads of four state committees which interface most importantly with S&T policy (the GKNT, Gosplan, Gossnab, and Gosstroy). The Chairman of the USSR Council of Ministers is designated "Premier" and is the effective, operational leader of the government.

The Council of Ministers, as the principal policymaking organ of the government, has general responsibility for organizing and administering all scientific, technical, and production activities in the Soviet economy. As illustrated in Figure 9-1, all state facilities ultimately report to the Council. Overseeing the critical planning function is a major occupation of the Council. Plans for all subordinate organs and facilities are derived from the national plan, which is inspired, prepared under the guidance of, and approved by the Council of Ministers. In the sphere of R&D planning and management, the scope and breadth of the Council's ultimate authority are illustrated by the following Soviet enumeration of pertinent Council responsibilities:

1. General administration of R&D
2. Resolution of all questions concerning the organization and administration of R&D
3. Development of measures to improve the management of R&D
4. Examination and approval of the "main directions" of R&D
5. Establishment of procedures for developing R&D plans and for introducing research results into the national economy
6. Development of the plan for S&T progress
7. Organization of S&T information
8. Finance of R&D
9. Resolution of questions on wages and working conditions of scientists and engineers
10. Training of scientific and engineering personnel
11. Resolution of questions about copyright, patents, and laws on invention and discovery.[4]

Each of these responsibilities forms the basic working orientation for one or more of the Council's state committees or specialized agencies.

Policy-Making Organs of the Union-Republic Governments

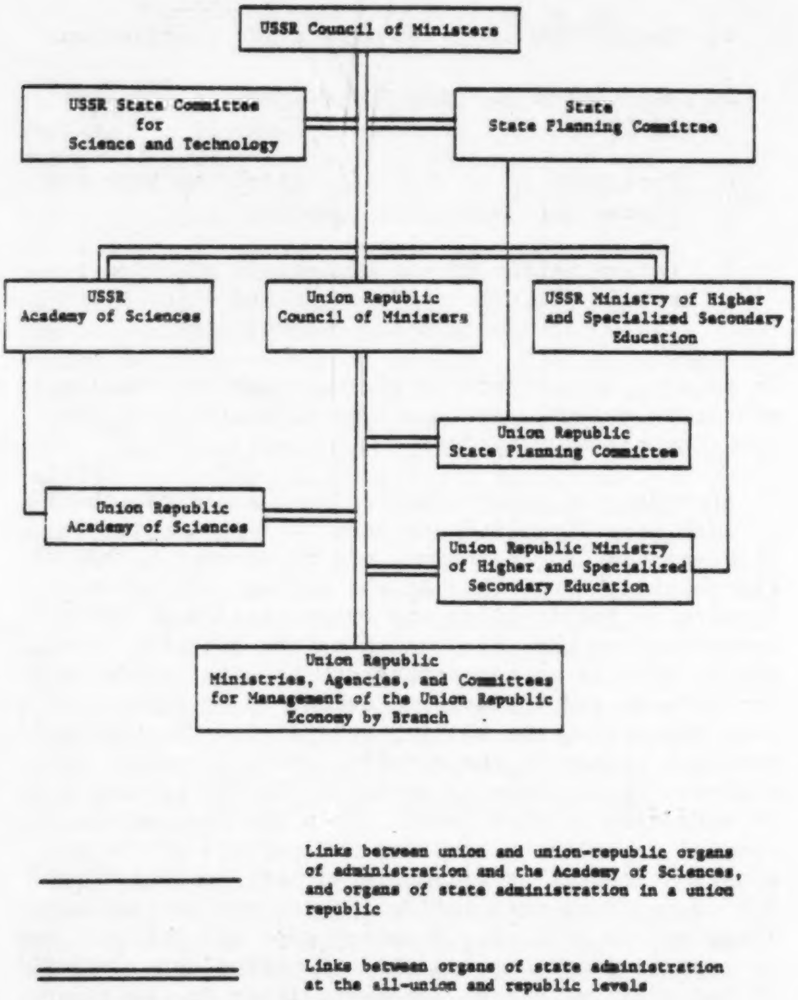
The governments of the union republics are patterned after the central government establishment, with a Supreme Soviet and a Council of Ministers in each republic. As with the central government, real administrative authority rests with the councils of ministers and, ultimately, the republic Communist Parties. The membership of a republic council of ministers consists of the heads of about 30 republic and republic-level union-republic ministries as well as republic counterparts to state committees and other specialized agencies.

Republic ministries are directly the province of the republic council of ministers. However, under the principle of "dual subordination" a union-republic ministry or agency is subordinate to both its respective republic council of ministers and its superior ministry in Moscow. Figure 9-3 illustrates the interrelationships between ministries and agencies of this type and all-union and republic policy-making organs. Note that each of the three types of institutional hierarchies concerned with science and technology--the academies of sciences, the industrial branch ministries, and the ministries of higher and specialized secondary education--is characterized in part by conditions of dual subordination.

The republic councils of ministers have authority over a broad range of issues pertaining to the direction of scientific and technical progress in the institutes and enterprises of the republic. Relevant functions include:

1. Consideration of draft plans developed by the central ministries for their subordinate organizations in the republic

FIGURE 8-3 ORGANIZATIONAL STRUCTURE OF SCIENCE POLICY AT THE UNION REPUBLIC LEVEL


USSR Council of Ministers
USSR State Committee for Science and Technology
State State Planning Committee
USSR Academy of Sciences
Union Republic Council of Ministers
USSR Ministry of Higher and Specialized Secondary Education
Union Republic State Planning Committee
Union Republic Academy of Sciences
Union Republic Ministry of Higher and Specialized Secondary Education
Union Republic Ministries, Agencies, and Committees for Management of the Union Republic Economy by Branch
Links between union and union-republic organs of administration and the Academy of Sciences, and organs of state administration in a union republic
Links between organs of state administration at the all-union and republic levels

Source: "USSR Short Answers," p. 2.

2. Submission of proposals to the USSR Gosplan and Council of Ministers

3. Establishment of procedures for organizing and administering scientific institutions of the republic

4. Establishment of new scientific institutions

5. Allocation of funds for scientific institutions

6. Coordination of republic activities with the appropriate all-union agencies

7. Determination of the competence of union-republic administrative organs to which scientific institutions are subordinate[5]

In general, the functions of the republic councils of ministers resemble and complement functions of the USSR Council of Ministers.

According to some Soviet science analysts, there is much more diversity and greater deficiencies in the organization, planning, and management of R&D on the republic level than at the center. The pluralization of institutions and fragmentation of administration are more pronounced on the republic level where there is no counterpart to the State Committee for Science and Technology, except in Georgia. In most republics, the leading role in R&D administration has passed to the republic state planning committee. Still there is no uniformity of procedure or operation at this level. Even the name of the special departments handling S&T matters at the gosplan and council of ministers varies from one republic to another, each reflecting its own particular focus and priorities. Existing gaps and neglect, not to mention conflicts, in the allocation and exercise of R&D administrative responsibilities in the republics cause difficulties and delays in the organization and flow of information to and from the Gorky Street headquarters of the USSR GKNT in Moscow. In the words of one Russian critic, the whole decision process becomes "overloaded and frozen." According to another, such an arrangement of structures and functions contradicts the demands for an optimal system of S&T planning and management.[6]

Functional Agencies Engaged in R&D Planning and Management

The role of state committees and other agencies depicted in Figure 9-1 essentially is to manage a subset of policy mechanisms on behalf of the Council of Ministers of the USSR and the republic councils. Administration of branch scientific and production activities, which is the responsibility of the ministries, depends upon provision of a number of common services, such as planning, finance, and supply. The Soviet leadership has chosen to concentrate provision of these services in particular state committees and functional ministries. Of these services, planning has the most immediate and widespread impact. Agencies concerned with planning of R&D and related activities are the State Committee for Science and Technology, the State Planning Committee, and the USSR Academy of Sciences. Other agencies manage complementary activities, such as finance and supply, or specialized operations which support planning and management, such as the maintenance of standards. While there are few R&D and production facilities administratively subordinate to these agencies, the agencies have broad powers to establish procedures and to issue binding orders on matters within their competence. These orders significantly influence the operation of all facilities throughout the Soviet economy.

The basic task of this network of functional interbranch agencies is to coordinate the vast and diverse Soviet R&D effort. On paper, these organizations possess formidable powers to enforce central priorities and to facilitate uniform S&T policies. In practice, however, they frequently lack the authority and means necessary to perform their integrating functions. Instead of regulating developments in their tangled branch constituencies, they are themselves at times being regulated and ignored. The ministries do not always accept the recommendations of these central agencies; instead, they pursue their own ways and wishes.[7]

To be sure, the actual workings of this machinery of coordination are much more complex than implied by the formal organization chart. The key to understanding Soviet policies lies not so much in the structure of institutions as in the fundamentally bureaucratic context in which they operate. The authority and activity of state committees are frequently circumscribed. Caught in a constant cross fire of pressures from competing and powerful organizations, each promoting its own interests and R&D goals, the committees find themselves challenged and constrained at every turn. Given the nature of their overlapping and shared responsibilities for R&D planning and management, the state committees are frequently forced to seek the approval of and some kind of accommodation with various branch ministries, government departments, and other state committees, not to mention Party agencies. They are integral parts of a giant maze of bureaucratic subsystems and circles of administrative confusion, rather than standing apart from it. As a result the state committees are forced to perform a continuous and difficult balancing act in which national goals and priorities are reconciled with the special interests of the numerous organizations that comprise and conduct the Soviet R&D effort. This process inevitably involves them in heavy political conflict, bargaining, and compromise. Although we still know little about the actual mechanics of power and processes of negotiation within the Soviet system, the reality of bureaucratic politics and its imprint on science policy are unmistakable.

With these caveats in mind, we can now briefly describe the formal functions of the major agencies involved in R&D planning and management at the central level. Discussion of the Academy of Sciences is taken up in the next section, as the Academy combines general planning and coordinating activities with administrative responsibility for a large number of R&D facilities.

The State Committee for Science and Technology (GKNT)

Within this governmental structure the State Committee for Science and Technology occupies a pivotal role. It acts as a "special balancing mechanism" for the USSR Council of Ministers, providing cohesion and coordination among the state committees and central departments.[8] That is, the GKNT is the agency that bears primary responsibility for ensuring the formulation and conduct of a unified S&T policy.

The GKNT, an all-union agency, was formed in 1965, replacing the union-republic State Committee for the Coordination of Scientific Research. Other predecessor organizations of the GKNT performing a similar function were the State Scientific and Technical Committee (1957-1961), the State Committee for New Technology (1955-1957), Gosplan (1951-1955), and the State Committee for the Introduction of Advanced Technology into the National Economy (1947-1951). Until 1947 the planning of science and technology was handled within Gosplan.[9]

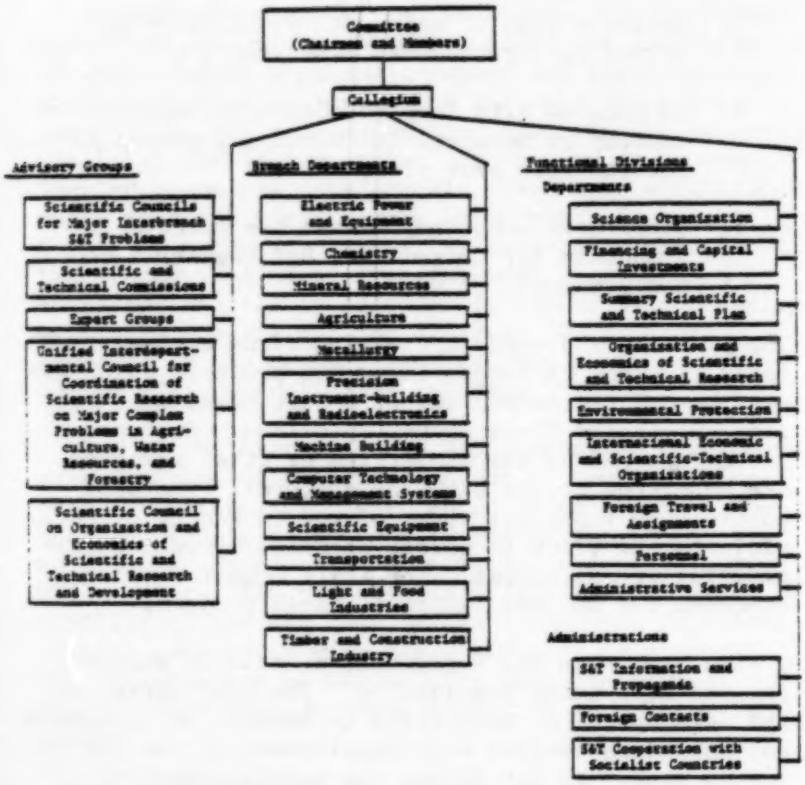
The State Committee itself consists of about 70 members, about a third of whom are members of the USSR Academy of Sciences and other academies. Some Government ministers and prominent industrial leaders sit on the GKNT. Among the ex officio members are the President of the USSR Academy of Sciences, the Chairman of the State Committee for Standards, the Chairman of the State Committee for Inventions and Discoveries, the Minister of Higher and Specialized Secondary Education, and a deputy chairman of Gosplan. Some top executives from the Committee staff are also members of the GKNT. The State Committee, as such, meets only once or twice a year to consider the main directions for the development of science and technology as well as to approve the list of priority R&D problems to be included in the five year plan.

The executive body of the GKNT is the Collegium, composed of fewer than 20 members and chaired by G.I. Marchuk, the Chairman of the State Committee. Besides the various deputy chairmen, the heads of certain departments and divisions plus a few Academicians make up the membership. The Collegium meets weekly and examines all problems that come before the GKNT. Though the Collegium acts as an advisory body, its decisions become decrees signed by Kirillin, and its orders are followed by all departments of the State Committee.

A simplified scheme of the internal organization of the GKNT is presented in Figure 9-4. In addition to various functional divisions charged with handling international liaison, information dissemination, science organization, and other tasks, departments have been established to monitor S&T developments in particular branches of industry, such as chemicals and machine building. Functioning under the GKNT is also an elaborate network of advisory bodies which assist in the analysis of institutional and policy problems of science and technology. Integral to this special consultative machinery are more than 60 scientific councils on major interbranch S&T problems, such as oceanography, new welding processes, and catalysis and its industrial utilization. Some 5,500 persons participate in the work of these councils, including nearly 160 academicians and corresponding members of the USSR and republic academies of sciences, more than 1000 doctors of science and about 1600 candidates of science.[10] The councils monitor and forecast developments in a particular field of science and technology, and/or progress in solving important, national engineering and economic problems.

The GKNT, as suggested by the above description, is the principal state agency concerned with overall S&T policy and performance. While possessing limited direct authority over the actual conduct of research, development, and innovation, the GKNT exercises important guidance and liaison functions for other ministries and agencies in R&D planning, coordination, and performance.

FIGURE 8-4 STRUCTURE OF THE USSR STATE COMMITTEE FOR SCIENCE AND TECHNOLOGY


Committee (Chairman and Members)
Collegium
Advisory Groups
Scientific Councils for Major Interbranch S&T Problems
Scientific and Technical Commissions
Expert Groups
Unified Interdepartmental Council for Coordination of Scientific Research on Major Complex Problems in Agriculture, Water Resources, and Forestry
Scientific Council on Organization and Economics of Scientific and Technical Research and Development
Branch Departments
Electric Power and Equipment
Chemistry
Mineral Resources
Agriculture
Metallurgy
Precision Instrument-building and Radioelectronics
Machine Building
Computer Technology and Management Systems
Scientific Equipment
Transportation
Light and Food Industries
Timber and Construction Industry
Functional Divisions
Departments
Science Organization
Financing and Capital Investments
Summary Scientific and Technical Plan
Organization and Economics of Scientific and Technical Research
Environmental Protection
International Economic and Scientific-Technical Organizations
Foreign Travel and Assignments
Personnel
Administrative Services
Administrations
S&T Information and Propaganda
Foreign Contacts
S&T Cooperation with Socialist Countries

ource: Louvan E. Nolting, The Structure and Functions of the U.S.S.R. State Committee for Science and Technology (Washington, D.C., 1979), p. 21.

With respect to R&D planning and interagency coordination, the GKNT

1. Prepares S&T forecasts and approves procedures for developing such forecasts
2. Draws up proposals for the main directions of R&D
3. Drafts a list of major S&T problems to be solved during the next five year plan
4. Cooperates with Gosplan, Gosstroy, and the Academy of Sciences in developing proposals for the five year plans for S&T
5. Cooperates with Gosplan and the Academy in proposals for introducing R&D results into the economy.[11]

The planning and coordination functions are particularly apparent on large, important projects which extend beyond the boundaries of a particular ministry, i.e., so-called "interbranch" problems. Such projects proposed by the ministries or other agencies are submitted to the GKNT for approval. The GKNT controls an important share of the financing of such projects and tries to settle disputes between participating organizations. The State Committee also oversees the implementation of these projects.

The GKNT also has a significant role in supporting and monitoring ongoing R&D. The GKNT works on the development of indicators to measure S&T progress and exercises control over development of the R&D resource base. It may decree the establishment or closing of institutions, and it approves overall requirements for machinery and equipment in the draft enterprise plans. Together with Gosplan and Gossnab it participates in supplying equipment to priority projects. With Gossnab it plans the financing of material and technical supply and finances the distribution of materials and equipment. In collaboration with the State Committee for Labor and Social

Problems, the GKNT develops proposals regarding the payment of scientists. Operationally, the committee has the authority to review important research being conducted at institutes, and it may issue binding directives to cease R&D work which is redundant or of no value.[12]

The State Planning Committee (Gosplan)

Gosplan has overall responsibility for the formulation of economic plans which guide the activities of middle-level management organs and their subordinate facilities in pursuit of the objectives laid down by the central leadership. Functioning essentially as the "nerve center" of the Soviet economy, Gosplan possesses considerable power over establishments in every field. As a union-republic agency, Gosplan's authority extends to activities throughout the economy. A simplified internal organizational chart for Gosplan is provided in Figure 9-5. Gosplan maintains departments for at least 30 different branches of the economy and also has departments concerned with general policy matters.

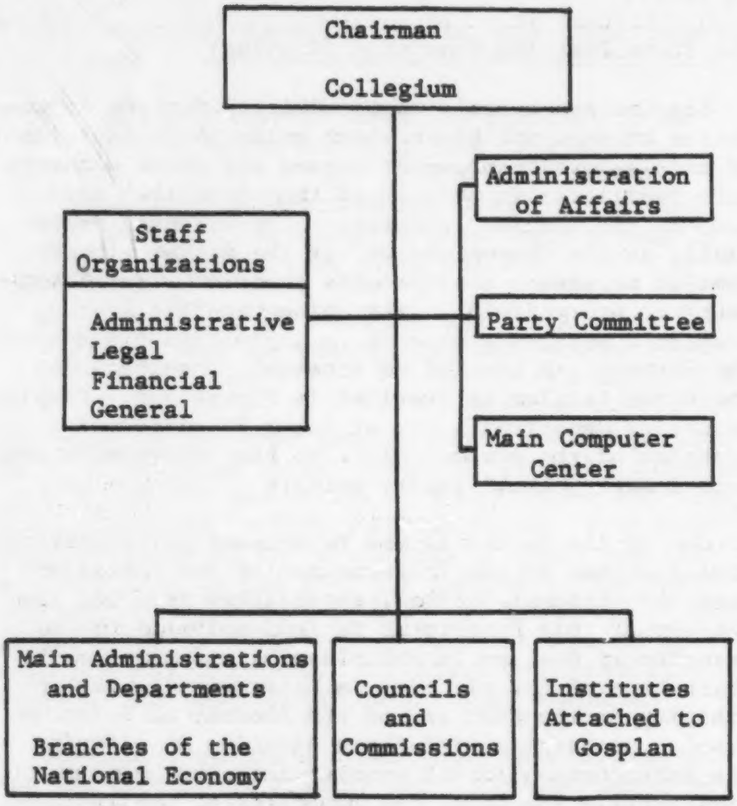
One of the latter is the Department for Comprehensive Planning of the Introduction of New Technology into the National Economy, established in 1966. The concern of this department is indicative of the orientation of Gosplan in R&D planning and management. While general R&D planning is primarily the responsibility of the GKNT and of the Academy of Sciences, Gosplan cooperates with these agencies in planning the introduction of R&D results into the economy. Specifically the pertinent functions of Gosplan include:

1. Collaboration with the GKNT in consideration of large interbranch (interministerial) S&T projects

2. Planning the introduction of new technology

3. Consideration of the overall volume of capital investment for S&T

FIGURE 8-5 GENERAL ORGANIZATION OF THE USSR STATE PLANNING COMMITTEE (GOSPLAN)


Chairman
Collegium
Administration of Affairs
Staff Organizations
Administrative
Legal
Financial
General
Party Committee
Main Computer Center
Main Administrations and Departments
Branches of the National Economy
Councils and Commissions
Institutes Attached to Gosplan

4. Collaboration with the Ministry of Finance and the GKNT to determine the levels of funding for S&T projects

5. Collaboration with Gossnab on planning material and technical supplies for R&D institutions

6. Participation in developing plans for training scientific manpower

7. Collaboration with the State Committee on labor and Social Problems and with the All-Union Council of Trade Unions on wages and working conditions for scientific personnel.[13]

Overall, a major concern of Gosplan is the integration of technical plan targets with Gosplan's principal concern, production plan targets.

The State Committee for Material and Technical Supply (Gossnab)

In the Soviet Union the allocation of commodities is centrally planned in accordance with the output targets specified by Gosplan. Supply of the most important articles is planned by Gosplan itself while supply of the remainder is planned by all-union or territorial organs of Gossnab, a union-republic agency. Inputs for industrial R&D are included in the overall material and technical supply system, while special provision has been made for acquisition of inputs by Academy and university facilities.

Facilities requiring inputs submit their requests to Gossnab, manager of the material and technical supply system. The transfer of items takes place only when Gossnab issues orders for their delivery. In general, Gossnab's authority is used to resolve conflicting demands on supply and to balance the material needs of producers and consumers.[14]

The State Committee for Construction Affairs (Gosstroy)

Gosstroy, a union-republic agency, plans and monitors capital construction and major renovation of facilities in the USSR. In S&T, Gosstroy develops and implements uniform policies directed at accelerating technical progress in construction to raise the effectiveness of this branch of industry.

Specifically, Gosstroy is charged with identifying basic S&T problems in construction, construction materials, and architecture; with developing plans for research to address such problems; and with coordinating the relevant R&D. Gosstroy's S&T plans are developed in collaboration with the GKNT and ministries as well as other agencies of the Council of Ministers.[15]

The State Committee for Standards (Gosstandart)

Gosstandart, an all-union body, assigns and directs work on the development of technical and economic standards, approves new standards that have been developed, and conducts statewide inspections to assure introduction of and adherence to approved standards.[16] Recently, Gosstandart has become increasingly concerned with the elaboration of uniform procedures for such activities as design and production assimilation. The growing importance attached to standardization relates to stepped-up efforts to improve product quality as well as to economize on design resources.

The State Committee for Inventions and Discoveries (Goskomizobreteniya)

The State Committee for Inventions and Discoveries maintains the state register of inventions and discoveries and seeks to promote innovation in Soviet science and industry. Among the responsibilities of the Committee are the issuance of "author certificates" and patents, the introduction of inventions into the economy, and the protection of state interests in inventions. Scientific discoveries are recognized through the issuance of diplomas. Author certificates, the most common form of recognition, differ from patents in that the rights to the invention accrue to the state, rather than to the inventors.

The certificates give the inventors/authors public acknowledgment, and if use of the invention or innovation results in production cost savings, monetary rewards often are given to the inventors.[17]

An important function of the Committee is the national dissemination of information about inventions. This is accomplished through the Committee's Central Scientific Research Institute of Patent Information and Technical Economic Investigation and through the journal Discoveries, Inventions, Industrial Prototypes, and Trade Marks (Otkrytiya, izobreteniya, promyshlennyye obraztsy, tovarnyye znaki).

The Higher Certification Commission (VAK)

The Higher Certification Commission approves the awarding of advanced degrees, makes all appointments to senior academic positions, and selects the higher educational institutions for advanced training in research. The Commission also has the authority to revoke degrees. The Commission is made up of professors, doctors of science, and members of the USSR and republic academies of sciences. Since 1974 VAK has been an agency of the USSR Council of Ministers. Previously, it was subordinate to the USSR Ministry of Higher and Specialized Secondary Education.

THE THREE INSTITUTIONAL SUBSYSTEMS PERFORMING R&D

Structurally, scientific R&D in the USSR is based within three different institutional subsystems: (1) academies of sciences; (2) industrial branch ministries; and (3) higher educational institutions or VUZy. The terms "academy science," "branch science," and "VUZ science" are commonly used in referring to this tripartite division of the research sector. Indeed, Soviet science is divided predominantly along institutional and administrative lines rather than according to different kinds of activity, such as "basic research," "applied research," or "innovation." The planning and financing of R&D are also conducted primarily on an institutional basis rather than by stages, projects, or programs.

Each of these subsystems has a distinct orientation. According to Nolting's estimates, fundamental research is concentrated overwhelmingly in the academy system, which accounts for roughly 67 to 79 percent of the total. About 10 to 13 percent is performed in the VUZy and from 8 to 23 percent in branch R&D organizations. The latter, however, conduct the vast bulk (90 to 95 percent) of officially reported applied scientific research and development. Only about 5 to 10 percent of official applied R&D is done by the academies of sciences and the VUZy together.[18] Though the amount of R&D performed in the VUZy has grown recently, higher educational institutions remain preoccupied with pedagogical functions. This predominantly teaching orientation reflects the Soviet pattern of research and education which has long been based on a degree of separation of the two that is much greater than in the United States.

In terms of expenditures and manpower, the academy system employs 9 percent of all scientific workers and receives 8 percent of official allocations for R&D. Branch scientific institutions of all kinds have 58 percent of the scientific workers and 80 percent of the official science budget. Higher educational institutions account for 28 percent and 9 percent, respectively. Only 3 percent of all scientific personnel and 2 percent of official science expenditures are concentrated in production enterprises and organizations.[19]

Organizational dissociation and administrative fragmentation are important features--and consequences--of this tripartite division of the R&D system. Each of these institutional networks is a relatively independent administrative hierarchy. Each has its own distinct focus, set of interests, reward structure, and approaches to the R&D function. All three subsystems, moreover, are separated generally not only from each other but from the world of production as well. In short, structural features help create and reinforce functional autonomy and nonintegrative attitudes throughout the Soviet R&D community.

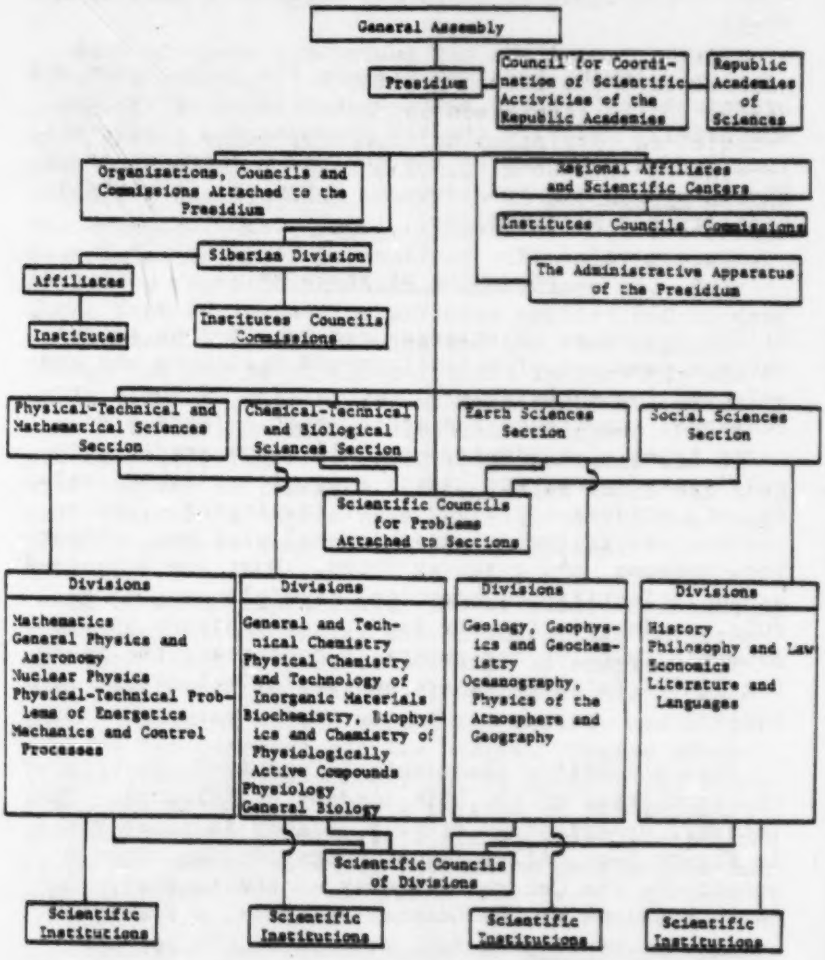
The following sections present the composition and organization of these three hierarchical subsystems, and briefly describe the R&D planning and management functions undertaken by the central management organ. The structure and functions of a typical industrial ministry are also outlined.

Academies of Sciences

The academies of sciences are prestigious organizations composed of scientists and engineers who are selected for membership in recognition of their professional competence and achievement. There are three types of academies--the all-union academy, republic academies, and branch academies. Subordinate to each academy are a number of institutes, laboratories, observatories, experimental stations, libraries, museums, and research ships. Most are organized around scientific or technical disciplines. As a rule, academy institutes tend to concentrate on fundamental research and generally constitute the leading Soviet facility in the particular scientific field.

This scientific leadership is particularly true of the facilities of the USSR Academy of Sciences. The internal organization of this Academy is illustrated in Figure 9-6. All full and corresponding members constitute the General Assembly of the Academy. Between sessions of the General Assembly, a Presidium consisting of elected full members of the Academy (Academicians) administers the Academy's affairs. The Presidium supervises 16 discipline-oriented divisions. These divisions oversee the activities of the Academy's research institutions. Between sessions of the Assembly, each Division is run by a Bureau headed by the Scientific-Secretary of the Division. Members of the Bureaus and the directors of research insti-

FIGURE 8-6 STRUCTURE OF THE USSR ACADEMY OF SCIENCES


General Assembly
Presidium
Council for Coordination of Scientific Activities of the Republic Academies
Republic Academies of Sciences
Organizations, Councils and Commissions Attached to the Presidium
Regional Affiliates and Scientific Centers
Institutes Councils Commissions
Siberian Division
Affiliates
Institutes
Institutes Councils Commissions
The Administrative Apparatus of the Presidium
Physical-Technical and Mathematical Sciences Section
Chemical-Technical and Biological Sciences Section
Earth Sciences Section
Social Sciences Section
Scientific Councils for Problems Attached to Sections
Divisions
Mathematics
General Physics and Astronomy
Nuclear Physics
Physical-Technical Problems of Energetics
Mechanics and Control Processes
Divisions
General and Technical Chemistry
Physical Chemistry and Technology of Inorganic Materials
Biochemistry, Biophysics and Chemistry of Physiologically Active Compounds
Physiology
General Biology
Divisions
Geology, Geophysics and Geochemistry
Oceanography, Physics of the Atmosphere and Geography
Divisions
History
Philosophy and Law
Economics
Literature and Languages
Scientific Councils of Divisions
Scientific Institutions
Scientific Institutions
Scientific Institutions
Scientific Institutions

Source: Gvishiani et al, Osnovnyye printsipy i obshchiye problemy upravleniya naukoy, pp. 182-183; Nolting, The Structure and Functions of the USSR State Committee for Science and Technology, p. 28.

tutes are elected by the Assembly of the Academy.

The institutes of the Academy tend to be centered in Moscow and in the Leningrad and Novosibirsk Divisions. However, the Academy has established a number of affiliates and scientific centers to promote the scientific and economic development of various regions. Their expressed purpose is to advance scientific progress on specific topics of more local importance so that the area can develop economically. The Soviet Academy has 8 affiliates and centers: Bashkir, Dagestan, Karelian, Kazan, Kola, Komi, the Far East, and the Urals. Each affiliate or center is managed by a presidium, consisting of heads of institutes and affiliate subdivisions, plant managers, and representatives from higher educational institutions in the region.

The Siberian Division of the Soviet Academy is unique in the Academy system. Unlike the discipline-oriented departments, it is governed by its own general assembly and presidium. It is administratively subordinate to both the USSR Academy and the Council of Ministers of the Russian Republic (RSFSR). Funding is provided by the RSFSR, which has no republic academy of its own. Thus, the Siberian Division has a certain measure of independence vis-a-vis the Soviet Academy. The principal facilities of the Siberian Division are located in Novosibirsk in what is known as Akademgorodok, or the Academy City.

The republic academies are dually subordinate to the USSR Academy and to their respective republic councils of ministers. Funding and administrative supervision are the responsibility of the councils of ministers; technical and functional supervision is provided by the USSR Academy.

The republic academies are more oriented toward solving industrial problems of their respective republic than is the Soviet Academy. To avoid duplication of effort, republic academies tend to be somewhat specialized and limited in scope. In a number of cases, however, the institutes of republic academies are on a par with those of the USSR Academy, and some, like the Paton Institute of Electric Welding of the Ukrainian Academy, are recognized as the leading Soviet institutions in their fields.

Despite efforts to decentralize and disperse scientific resources, however, Soviet science remains highly concentrated in a few large urban centers. Moscow alone boasts one-fourth of all scientific workers, 34 percent of all doctors of science and 26 percent of all candidates of science. Here also are the most qualified researchers: 45 percent of all scientists with the title of professor; 72 percent of all full members and 64 percent of all corresponding members of the USSR Academy. In just three cities--Moscow, Leningrad, and Kiev--are concentrated one fourth of all scientific institutions, nearly 40 percent of all R&D being performed in the country, and more than 45 percent of the total allocations to scientific research and development.[20]

Finally, in addition to the Soviet and republic academies of sciences, there are several specialized branch academies under the ministries of their respective fields. Some significant research facilities are subordinate to these academies, particularly in biomedicine. The specialized academies of interest in R&D planning and management are the Academy of Medical Sciences under the USSR Ministry of Health, the Academy of Agricultural Sciences under the USSR Ministry of Agriculture, and the Academy of Pedagogical Sciences under the USSR Ministry of Higher and Specialized Secondary Education. It may be noted that the branch academy system was considerably reduced in the 1960s and many of its institutions transferred to the republic academies. Table 9-1 supplies data concerning the size and composition of the all-union, republic, and branch academies. Table 9-2 provides data on the scientific centers of the USSR Academy of Sciences.

The planning and managerial authority of the USSR Academy in fundamental research is extensive. Reporting directly to the USSR Council of Ministers, the

TABLE 8-1
USSR, UNION REPUBLIC, AND BRANCH ACADEMIES OF SCIENCES (at the end of 1976)

ACADEMY	YEAR FOUNDED	NUMBER OF FULL AND CORRESPONDING MEMBERS	NUMBER OF SCIENTIFIC INSTITUTIONS	NUMBER OF FULL-TIME SCIENTISTS	WITH ADVANCED DEGREES	
					DOCTOR OF SCIENCES	CANDIDATE OF SCIENCES
USSR Academy of Sciences	1724[a]	733	244	42,951	3,943	18,785
Ukrainian SSR Academy of Sciences	1919	300	70	12,250	904	5,753
Belorussian SSR Academy of Sciences	1928	126	32	4,736	187	1,336
Uzbek SSR Academy of Sciences	1943	92	30	3,545	189	1,509
Kazakh SSR Academy of Sciences	1945	129	31	3,736	183	1,541
Georgian SSR Academy of Sciences	1941	106	38	5,356	344	1,778

TABLE 8-1 (continued)

Azerbaydzhan SSR Academy of Sciences	1945	102	28	4,242	249	1,704
Lithuanian SSR Academy of Sciences	1941	49	11	1,555	60	724
Moldavian SSR Academy of Sciences	1961	41	19	895	59	521
Latvian SSR Academy of Sciences	1946	51	16	1,688	76	744
Kirgiz SSR Academy of Sciences	1954	44	18	1,460	68	515
Tadzhik SSR Academy of Sciences	1951	46	17	1,262	51	512
Armenian SSR Academy of Sciences	1943	88	31	2,898	182	933
Turkmen SSR Academy of Sciences	1951	46	14	883	40	410
Estonian SSR Academy of Sciences	1946	42	13	952	63	532

TABLE 8-1 (continued)

USSR Academy of Art	1947	127	4[c]	349	16	131
All-Union Academy of Agricultural Sciences imeni Lenin	1929	203	169	11,315	497	5,660
USSR Academy of Medical Sciences	1944	254	42	5,488	929	3,262
USSR Academy of Pedagogical Sciences[b]	1943	127	14	1,687	128	809
RSFSR Academy of Communal Economics	1931	- -	5	428	10	206

[a] The Academy opened in 1725

[b] Until 1966, The Academy of Pedagogical Sciences RSFSR

[c] Including 2 VUZy

Source: Narodnoye khozyaystvo SSSR za 60 let; yubileynyy statisticheskiy yezhegodnik (The National Economy of the USSR for 60 years: Jubilee Statistical Yearbook) (Moscow, 1977), p. 144

TABLE 8-2

REGIONAL AFFILIATES AND SCIENTIFIC CENTERS OF THE USSR ACADEMY OF SCIENCES
(at the end of 1976)

	NUMBER OF INSTITUTIONS	NUMBER OF SCIENTIFIC WORKERS	WITH ADVANCED DEGREES	
			DOCTOR OF SCIENCES	CANDIDATE OF SCIENCES
Siberian Division of the USSR Academy of Sciences				
Including Affiliates	49	6,289	436	2,982
Buryat	4	285	15	145
Eastern Siberia	9	1,068	53	467
Yakutsk	6	511	20	220
Scientific Centers of the USSR Academy of Sciences				
Far Eastern	19	1,976	78	762
Urals	13	1,779	102	698
Affiliates of the USSR Academy of Sciences				
Bashkir	8	501	30	219
Dagestan	4	363	12	151
Karelian	8	360	17	187
Kola	8	763	15	225
Komi	4	307	9	124
Kazan	5	517	31	256

TABLE 8-2 (continued)

Source: *Narodnoye khozyaystvo SSSR za 60 let; yubileynyy statisticheskiy yezhegodnik* (The National Economy of the USSR for 60 years: Jubilee Statistical Yearbook) (Moscow, 1977), p. 145.

Academy has overall responsibility for development of R&D in natural and social sciences. In these areas, the Academy functions as a statewide center for the development of science policy. It defines the main directions in those fields, plans and coordinates the R&D work, and carries out overall scientific direction of projects on the most important problems in all research institutions, regardless of their departmental affiliation. Working with the republic councils of ministers, the Presidium of the Soviet Academy coordinates the work of the republic academies.

The comprehensiveness of the Academy's planning authority justifies designating the Academy as a central-level functional agency as well as a major performing institutional subsystem, as previously noted. Together with the GKNT and Gosplan, the Academy coordinates and develops R&D plans not only for Academy institutions but also for any facility conducting work in the fields under its jurisdiction. The Academy also makes proposals on funds, personnel, and materials for R&D as a whole in the USSR. With the GKNT, the Academy submits proposals to the USSR Council of Ministers regarding the introduction of new technology into the national economy. The work of the Academy, especially in the natural and social sciences, is funded almost entirely from the state budget, although the GKNT allegedly influences and possibly controls the size of the Academy budget.

In addition to these general responsibilities, the USSR Academy and republic and branch academies direct the activities of their subordinate establishments. At sessions of the General Assembly, summary R&D plans are approved, new research directions are discussed, and the creation of new facilities is considered. Scientific divisions, in turn, monitor the formulation and execution of plans at specific facilities.

Finally, the Academy also engages in education, especially advanced training, of scientific manpower. Many Academy institutes provide programs for graduate study and award advanced degrees. Many members of the Academy teach in universities.

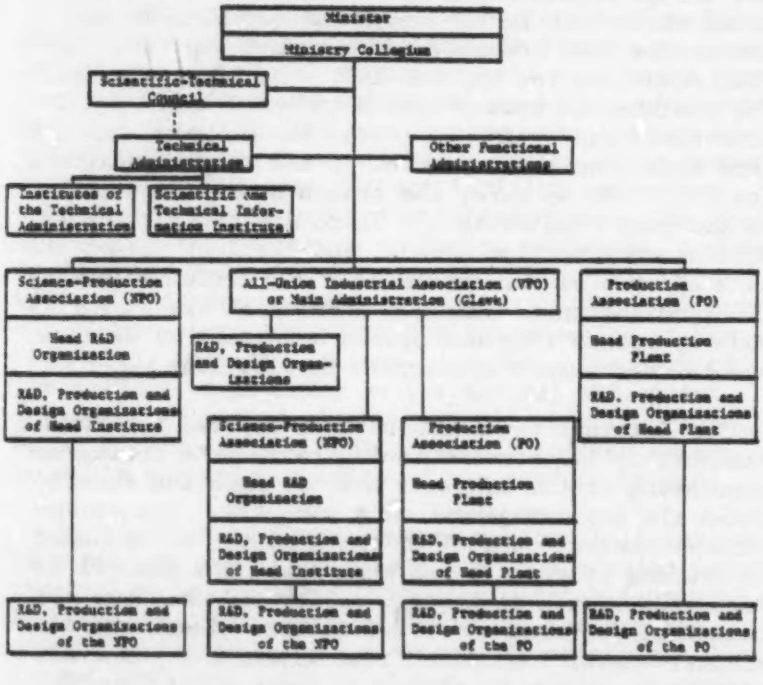
Industrial Branch Ministries

Soviet industry is organized on a branch-of-industry concept; the branch is defined by its products, such as communications equipment industry, defense industry, and machine tool and tool building industry. Each branch is managed by an industrial ministry of the Council of Ministers. Currently there are about 30 union-level industrial ministries in the USSR Council of Ministers. The research institutes and design organizations subordinate to the industrial ministries at the union and republic levels constitute what probably are the most important Soviet resources for applied R&D. As already noted, the ministerial branch system includes half of all scientists and engineers in the Soviet Union and garners more than three-fourths of all the expenditures for R&D. To be sure, the branch sector of science is not just "industrial." There are other branches, such as construction, trade, and justice, though the bulk of this sector consists of industrial scientific organizations. Some non-industrial branch R&D is done by branch VUZy and branch academies as well as specialized branch scientific institutions.

The internal organization of a typical industrial ministry is illustrated in Figure 9-7. A collegium consisting of the minister and his deputies constitutes the top management of a ministry. The scientific-technical council of the ministry is composed of leading scientists and engineers; the council deliberates branch technology policy and monitors the technical performance of facilities. There are also ministry-level functional administrations concerned with such matters as planning, finance, and supply. Of these subdivisions, the technical administration is charged with overseeing the development and implementation of technology policy within the ministry and, specifically, with the formulation of the technical chapters of the ministry plan.

The basic units of Soviet industry traditionally have been and, to a large extent, still are research institutes, design bureaus, and production enterpris-

FIGURE 8-7 ORGANIZATION AND MANAGEMENT OF R&D IN A UNION LEVEL INDUSTRIAL MINISTRY


Minister
Ministry Collegium
Scientific-Technical Council
Technical Administration
Other Functional Administrations
Institutes of the Technical Administration
Scientific And Technical Information Institute
Science-Production Association (NPO)
Head R&D Organization
R&D, Production and Design Organizations of Head Institute
All-Union Industrial Association (VPO) or Main Administration (Glavk)
R&D, Production and Design Organizations
Production Association (PO)
Head Production Plant
R&D, Production and Design Organizations of Head Plant
Science-Production Association (NPO)
Head R&D Organization
R&D, Production and Design Organizations of Head Institute
Production Association (PO)
Head Production Plant
R&D, Production and Design Organizations of Head Plant
R&D, Production and Design Organizations of the NPO
R&D, Production and Design Organizations of the NPO
R&D, Production and Design Organizations of the PO
R&D, Production and Design Organizations of the PO

Source: Adapted from "USSR Short Answers," p. 44 and Eugene Zaleski, "Planning and Financing of Research and Development in the U.S.S.R.," in John R. Thomas and Ursula M. Kruse-Vaucienne, eds., Soviet Science and Technology: Domestic and Foreign Perspectives (Washington, D.C., 1977), p. 304.

es. These were grouped by product line and subordinated to units of their respective ministries known as chief directorates or main administrations (*Glavki*). After many years of experimentation with different management forms, the USSR Council of Ministers decreed in 1973 that the industrial ministries would switch to a "2-link" or "3-link" management structure in which the production main administrations would be abolished and replaced by industrial associations. Under this new format the basic units are to be production and science-production associations which consist of groups of production enterprises and R&D institutions. Production and science-production associations are to be subordinate either to industrial associations or directly to the central ministry apparatus. The alternative structures are illustrated in Figure 9-7. At present, most industrial ministries have made or are making the transition to the new system.

Perhaps the most important structural feature of branch science is that R&D and production activities have for a long time been organizationally separate from each other. Even within the same ministry research and development establishments and production units have come under different channels of planning, management, finance, and supply. This pattern of organization has tended to create strong departmental barriers against effective linking of research with production. A major purpose, in fact, of the management restructuring now underway at the ministries is to break down some of these obstacles that are rooted largely in basic structural design.

An industrial ministry has broad responsibilities in planning and managing R&D in its special area. The ministry is responsible for evaluating the economic and technological level of production and of product output. It determines the best ways of utilizing R&D results and of raising the level of development of the branch on the basis of S&T achievements both at home and abroad. Ministerial authorities not only plan and oversee the solution of the most important branch S&T problems but they also participate--sometimes as the lead agency--in the solution of comprehensive interbranch problems. In cooperation with appropriate USSR ministries and agencies the ministry resolves questions regarding the withdrawal of obsolete products from production and use. Supervision over the observance of standards and the status of means of measurement and tests falls within its competence. For individual types of products for which there are no state standards the ministry approves branch technical norms. Each ministry also prepares recommendations concerning the patenting of inventions abroad as well as the purchase of foreign licenses for the latest machinery, equipment, materials, and technological processes.[21] As illustrated, responsibilities include those of "line" planning and administration of branch facilities and programs, along with interaction between the ministry and state organs on functional issues, such as standards and invention policies.

The Ministry of Higher and Specialized Secondary Education

Institutions of higher education (VUZy), their teaching staffs, and their students constitute an important R&D resource and the third relatively independent subsystem. For example, Moscow State University alone has four subordinate research institutes, 33 basic science and industrial laboratories, 200 laboratories in the teaching departments, and 9 teaching-research stations. More than 4,000 of its teaching staff participate in research activities. In total, there were more than 800 civilian higher educational institutions in the Soviet Union in 1972. Some 60 percent of the daytime students in the VUZy reportedly participate in research.[22] Table 9-3 provides data on the distribution of scientific workers by branch of science in 1970 and permits a comparison of the numbers in VUZy with those in scientific research institutes. Fully one-third of the scientific workers are in the VUZy, though they account for less than five percent of all R&D performed in the country. Nonetheless, about 70 percent of all research conducted on the basis of economic contracts with industry is performed at the VUZy.[23]

TABLE 8-3

DISTRIBUTION OF SCIENTIFIC WORKERS BY BRANCH OF SCIENCE: 1973
(SCIENTIFIC RESEARCH INSTITUTES AND HIGHER EDUCATIONAL INSTITUTIONS)

Branches of Science	Number of Scientists	In NII and VUZ With Advanced Degrees				Number of Scientific Teaching Workers	VUZy			
		Doctor of Sciences	Percent	Candidate of Sciences	Percent		Doctor of Sciences	Percent	Candidate of Sciences	Percent
Physical-Mathematical	95272	2689	2.8	22403	23.5	46499	1216	2.6	12322	26.5
Chemical	45815	1320	2.9	13284	29.0	15222	556	3.7	5940	39.0
Biological	37362	2460	6.6	17182	46.0	11196	799	7.1	5362	47.9
Geology and Mineralogy	20362	1075	5.3	7767	38.1	3779	333	8.8	1733	45.9
Technical	409470	4738	1.1	3512	15.5	92058	2373	2.8	29070	31.6
Agriculture and Veterinary Medicine	35446	1348	3.8	4391	61.2	9862	799	8.1	5307	53.8
History and Philosophy	37177	1681	4.5	15067	40.5	23178	886	3.8	10906	47.0
Economics	57518	923	1.6	14929	25.9	22012	519	2.4	8480	38.5
Philology	48721	882	1.8	9310	19.1	41476	510	1.2	6896	16.6
Geography	7242	341	4.7	2676	36.9	2871	148	5.2	1241	43.2
Jurisprudence	4765	363	7.6	2381	49.9	2748	241	8.8	1446	52.6
Pedagogy	31283	159	0.5	4498	14.4	22507	94	0.4	3289	14.6
Medicine and Pharmacy	69957	5011	10.0	28539	57.1	26602	2581	9.7	14171	53.3
Art	12182	139	1.1	1262	10.3	8936	70	0.8	701	7.8
Architecture	2590	59	2.3	814	31.4	1320	33	2.5	416	31.5
Psychology	1926	100	5.2	768	39.9	1228	45	3.9	521	42.4
Other	30663	328	1.1	5527	18.0	17358	231	1.3	3333	19.2
Total	927709	23616	2.5	224490	24.2	348872	11643	3.3	111094	31.8

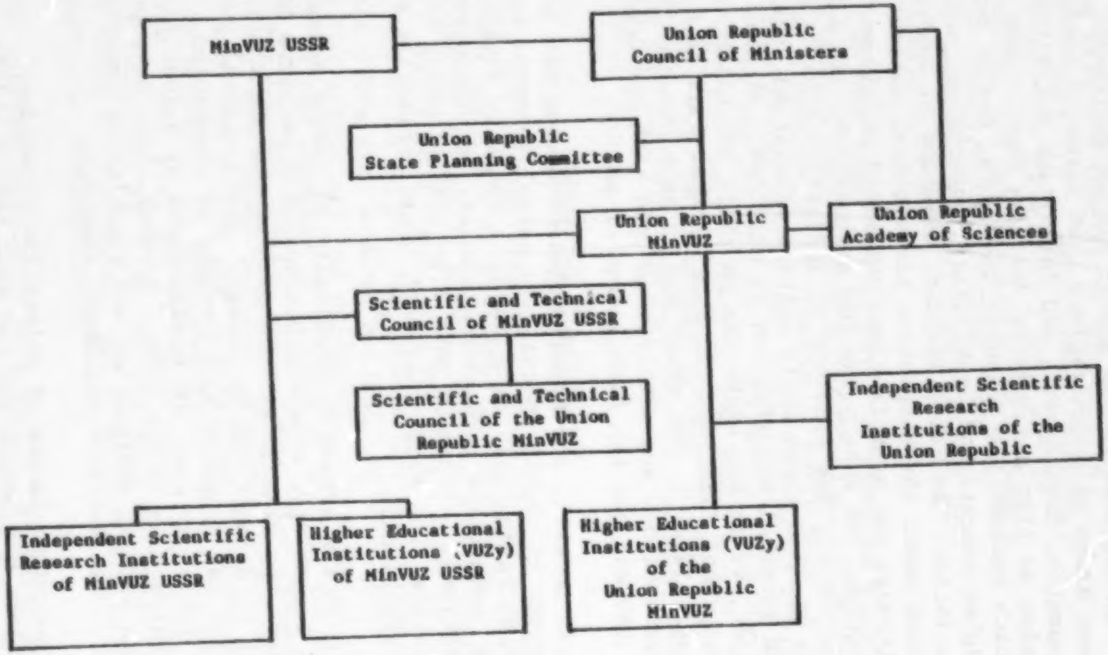
Source: B. M. Remennikov, Vysshaya shkola v sisteme vosproizvodstva rabochey sily v SSSR (Moscow, 1973), p. 155.

The structure of the Soviet system of higher education is complex, involving many ministries, agencies, and Communist party organizations at both the union and republic levels. The Ministry of Higher and Specialized Secondary Education (MinVUZ), which has direct administrative authority over the vast majority of VUZy, is preeminent, however. In addition, this Ministry maintains a number of independent research and experimental facilities. Because the Ministry is a union-republic ministry and because it administers research ranging from fundamental to narrowly applied, the relationship of MinVUZ to superior, subordinate, and other organs is complex. This relationship is depicted in Figure 9-8.

In general, the plans of the Academy and Gosplan concerned, respectively, with fundamental research and innovation must be accommodated in MinVUZ planning. However, the Ministry of Higher and Specialized Secondary Education as a rule administers directly the scientific work of the majority of VUZy except for those establishments whose specialty has made it more logical to place them under the jurisdiction--or partial jurisdiction--of a branch ministry. The administrative functions of MinVUZ include examination and approval of subordinate facility R&D plans and control over certain aspects of funding.

As previously noted, however, higher educational institutions have been assigned primarily a pedagogical function, while the Academy and ministerial subsystems have been the main centers for advanced R&D. Though the separation of research from teaching was never absolute, the separation of the two realms was striking, particularly compared to the United States. Since the 1950s the Soviet leadership has taken steps to build closer links between education and research, between the VUZy and Academy institutes, on the one hand, and between the VUZy and the world of industrial R&D and production, on the other. Indeed, various research complexes have been formed in some areas which seek to bring all three institutional subsystems into intimate contact and joint action.

FIGURE 8-8 THE ADMINISTRATIVE NETWORK OF THE USSR MINISTRY OF HIGHER AND SPECIALIZED SECONDARY EDUCATION (MinVUZ)


MinVUZ USSR
Union Republic Council of Ministers
Union Republic State Planning Committee
Union Republic MinVUZ
Union Republic Academy of Sciences
Scientific and Technical Council of MinVUZ USSR
Scientific and Technical Council of the Union Republic MinVUZ
Independent Scientific Research Institutions of the Union Republic
Independent Scientific Research Institutions of MinVUZ USSR
Higher Educational Institutions (VUZy) of MinVUZ USSR
Higher Educational Institutions (VUZy) of the Union Republic MinVUZ

Source: "USSR Short Answers," p. 46.

THE BASIC UNITS

At the base of the Soviet S&T establishment is a vast array of organizations that actually conduct research, development, and innovation activities. Below we list and briefly describe these basic units which include the research institute, design bureau, higher educational institution, enterprise, and association. As noted earlier, examples of each are found under the respective hierarchical subsystems although the organizations concerned mainly with production, the enterprise and association, are almost exclusively the province of industrial ministries. For each of these basic units a simplified chart of the internal organization is provided. At this point, we do not elaborate on their R&D planning and management functions, in part because this is discussed later in the study and in part because the organizations are mainly concerned with the conduct of R&D and not the formulation of policy.

In general, the organization of Soviet R&D is a network of highly specialized establishments, each concentrating only on a specific stage or stages of the research-to-production process. Furthermore, functional performers have also traditionally been separate from each other both organizationally and geographically.

With the growth in complexity of Soviet science and technology, however, conventional patterns and underlying principles have been undergoing change, both by default and by design. Institutional evolution has resulted in a variety of structures. Today there are over 100 designations of scientific organizations in the USSR. However, the correspondence between designation and function is generally poor. One American authority observes:

> The nomenclature of scientific organizations has become for the most part a hodgepodge rather than an indication of functional type. Today numerous scientific

> research institutes do only design or prototype work and no research, others do only research and no development, some research institutes concentrate almost entirely on experimental testing or assisting industrial plants in innovation, and many design agencies have large research subdivisions, some of them operating primarily as research organizations.[24]

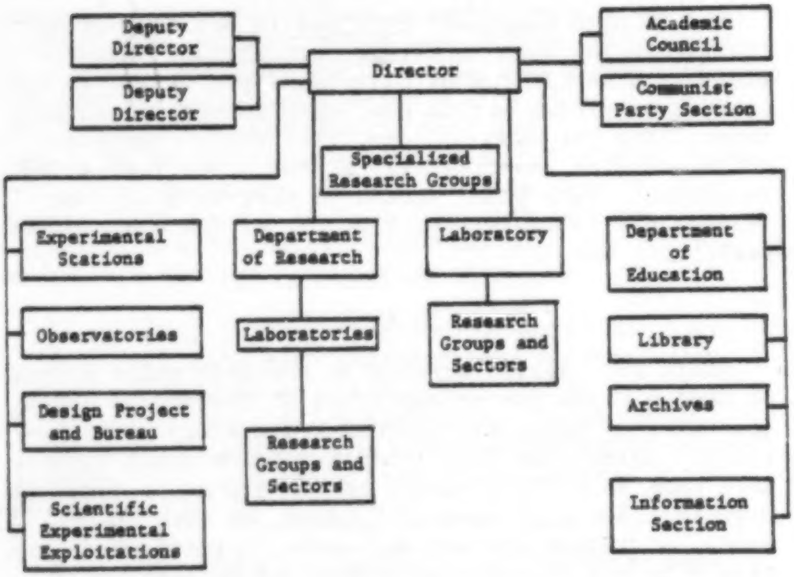
At the same time, S&T activity is becoming steadily integrated with industrial production. Organizational dissociation of functional performers is increasingly giving way to new, more integrated structures, like the associations. The whole organizational edifice, particularly at the lower levels, is in motion. This point should be kept in mind when reading the following descriptions of the basic units performing R&D.

Research Institutes

Basic and applied scientific research and a number of design tasks are accomplished at institutes under academies of sciences, MinVUZ, and the branch ministries. While some institutes are quite small with no more than 40 to 50 persons, others are major research organizations with several hundred, or even thousands, of scientists and engineers. Institutes vary widely in the presence or absence of design, technical drafting, and testing facilities. Some research institutes are "broad-profile," engaging in all stages of R&D, and others are "specialized," limited to applied research, to development, or to testing prototypes. Some also act as "head" institutes determining technical policies and research assignments for a group of institutes, and others operate independently or subordinately.[25]

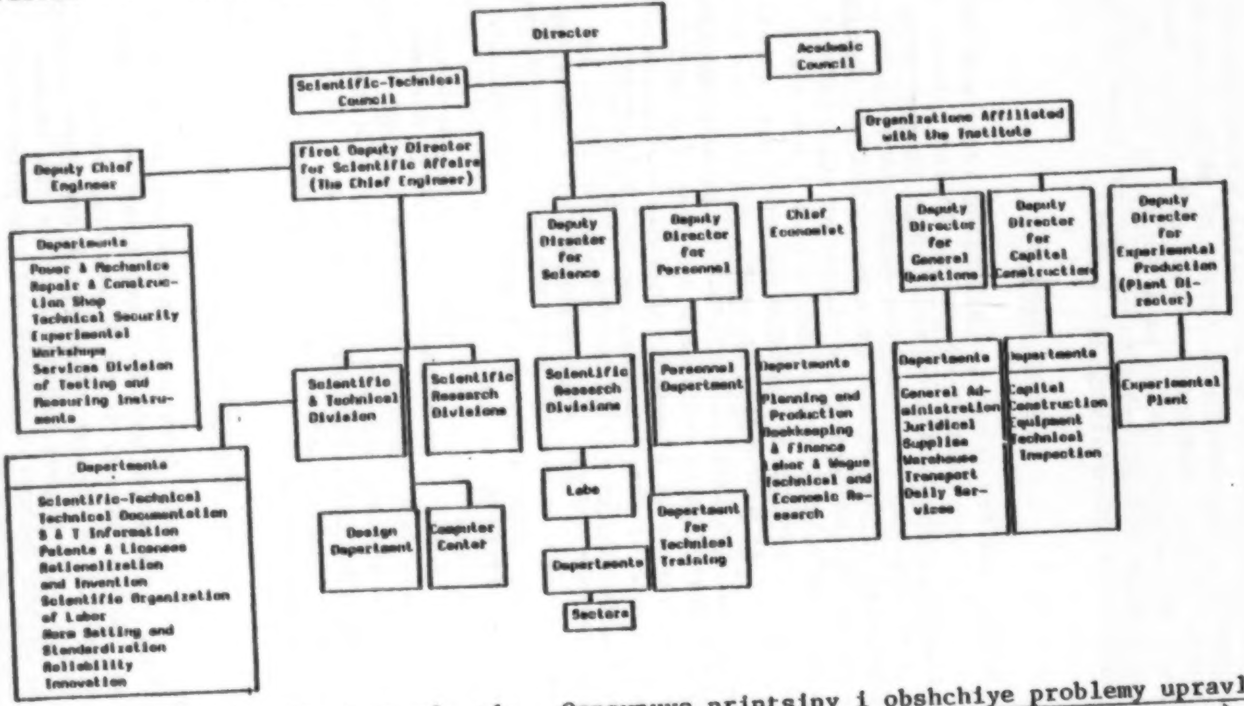
The internal structure of a typical research institute of the Academy of Sciences is depicted in Figure 9-9. Similarly, Figure 9-10 provides an overview of the organizational structure of a research

FIGURE 8-9 ORGANIZATIONAL STRUCTURE OF A RESEARCH INSTITUTE OF THE USSR ACADEMY OF SCIENCES


Deputy Director
Deputy Director
Director
Academic Council
Communist Party Section
Specialized Research Groups
Experimental Stations
Observatories
Design Project and Bureau
Scientific Experimental Exploitations
Department of Research
Laboratories
Research Groups and Sectors
Laboratory
Research Groups and Sectors
Department of Education
Library
Archives
Information Section

Source: Eugene Zaleski et al, eds., Science Policy in the USSR (Paris, 1969), p. 220.

FIGURE 8-10 ORGANIZATIONAL STRUCTURE OF A RESEARCH INSTITUTE OF AN INDUSTRIAL MINISTRY


Director
Academic Council
Scientific-Technical Council
Organizations Affiliated with the Institute
Deputy Chief Engineer
First Deputy Director for Scientific Affairs (The Chief Engineer)
Departments
Power & Mechanics
Repair & Construction Shop
Technical Security
Experimental Workshops
Services Division of Testing and Measuring Instruments
Scientific & Technical Division
Scientific Research Divisions
Departments
Scientific-Technical
Technical Documentation
S & T Information
Patents & Licenses
Rationalization and Invention
Scientific Organization of Labor
Norm Setting and Standardization
Reliability
Innovation
Design Department
Computer Center
Deputy Director for Science
Scientific Research Divisions
Labs
Departments
Sectors
Deputy Director for Personnel
Personnel Department
Department for Technical Training
Chief Economist
Departments
Planning and Production
Bookkeeping & Finance
Labor & Wages
Technical and Economic Research
Deputy Director for General Questions
Departments
General Administration
Juridical
Supplies
Warehouse
Transport
Daily Services
Deputy Director for Capital Construction
Departments
Capital Construction
Equipment
Technical Inspection
Deputy Director for Experimental Production (Plant Director)
Experimental Plant

Source: D. M. Gvishiani et al, eds., Osnovnyye printsipy i obshchiye problemy upravleniya naukoy (Basic Principles and General Problems in the Management of Science) (Moscow, 1973), p. 226.

institute attached to an industrial branch ministry. In general, the structural format of an Academy institute is less complex than that of a branch institute. The Academy system as a whole, in fact, is less bureaucratically organized and run than the R&D subsystem of the ministries.

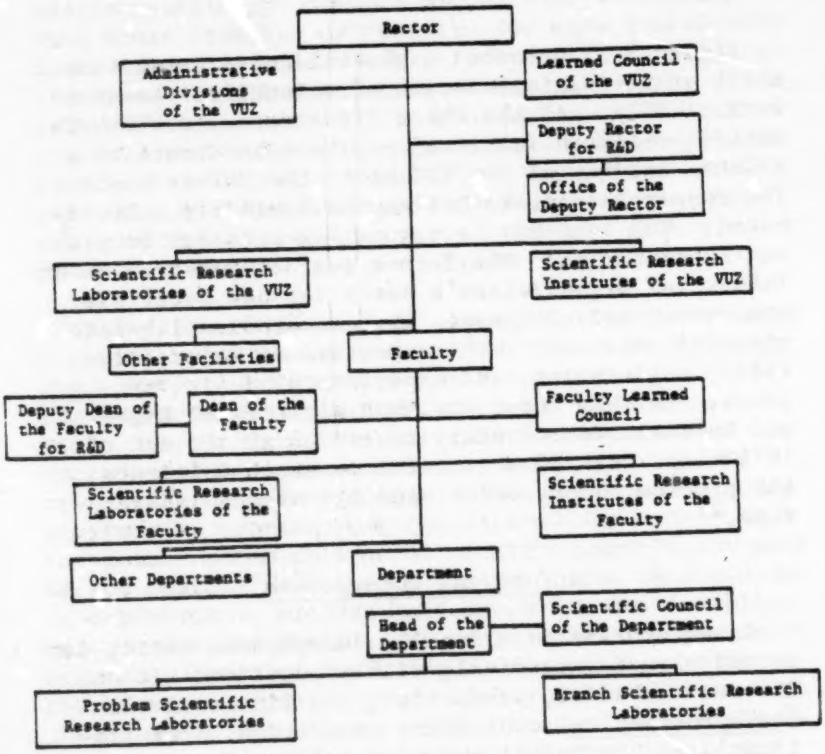
Design Bureaus

Design and development engineering tasks are carried out by organizations known as design bureaus or institutes. The design bureaus range in size from small groups within production enterprises to large independent organizations of several hundred design engineers and technologists known as experimental plants. While some design facilities limit their work to designing new products and machines, others build and test prototypes as well. Still other organizations are primarily engaged in process designing, or designing of machinery and installations, and development of processes for the manufacture of new products or the modernization of production. They are variously titled design-technological bureaus, project-design and technological bureaus, or scientific research project-technological institutes. In addition, there are so-called project institutes that specialize in the designing and planning of new plants or renovation of old enterprises. Although scientific research is conducted at design bureaus, it is of secondary importance to work on product and process development and the building of prototypes. Some design bureaus, however, do extensive industrial research and are often indistinguishable from research institutes.[26]

Higher Educational Institutions

Most educational institutions conduct research of some kind. These include (1) comprehensive universities, such as Moscow State University, where a broad curriculum of natural sciences and humanities is offered; (2) higher schools such as the Bauman Moscow Higher Technical School and the polytechnic institutes, where a variety of engineering courses

FIGURE 8-11 ORGANIZATION AND MANAGEMENT OF R&D IN A HIGHER EDUCATIONAL INSTITUTION (VUZ)


Rector
Administrative Divisions of the VUZ
Learned Council of the VUZ
Deputy Rector for R&D
Office of the Deputy Rector
Scientific Research Laboratories of the VUZ
Scientific Research Institutes of the VUZ
Other Facilities
Faculty
Deputy Dean of the Faculty for R&D
Dean of the Faculty
Faculty Learned Council
Scientific Research Laboratories of the Faculty
Scientific Research Institutes of the Faculty
Other Departments
Department
Head of the Department
Scientific Council of the Department
Problem Scientific Research Laboratories
Branch Scientific Research Laboratories

Source: "USSR Short Answers," p. 88.

may be pursued; and (3) a large number of specialized single-curriculum institutes such as the Leningrad Institute for Aviation Instrument Construction and the Mendeleyev Moscow Chemical Technical Institute. The institutes concentrate on applied research, most of which is funded through contracts with industry. University research generally is conducted within departmental structures by an individual professor; but in some universities special scientific research institutes have been formed.

Figure 9-11 presents a generalized organizational chart of the administration of scientific research work in VUZy. As the chart illustrates, a VUZ scientific research institute may be subordinate to a related faculty of the VUZ or to the VUZ as a whole. The research laboratories may be similarly subordinated. VUZ labs may be branch laboratories or problem laboratories. The former conduct research on an industrial organization's needs for new materials, processes, and equipment, whereas problem laboratories are created for the execution of major scientific, engineering, and experimental design projects. In VUZy under the USSR Ministry of Higher and Specialized Secondary Education at the end of 1971 there were 55 scientific research institutes, 419 problem laboratories, and 528 branch laboratories.[27]

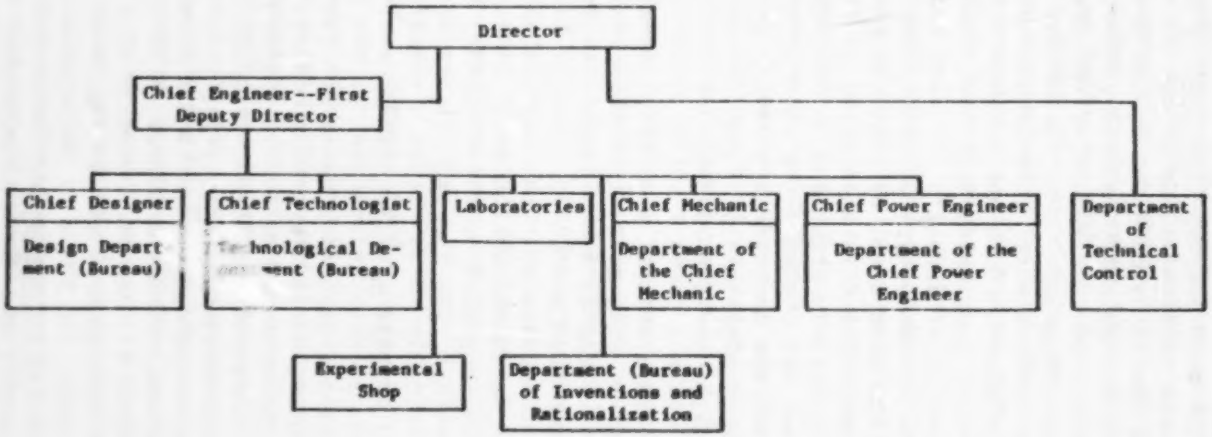
Industrial Enterprises

An enterprise is a legally independent entity concerned almost exclusively with production. It has its own technical, production, and financial plan (tekhpromfinplan) containing production, organizational, and technical chapters and targets, in principle well integrated. It has its own assets, including working capital. When on an independent balance sheet, it has an account in the State Bank. It most frequently includes a single plant.

The term enterprise (predpriyatiye) is also a generic term that covers a number of forms of production organization. One is the plant (zavod), which is an industrial enterprise with mechanized means of production. The term factory (fabrika) is used primarily for plants in light industry and for plants engaged in the initial processing of raw materials. When several technologically related production activities are combined, the resulting enterprise is called a combine (kombinat). A combine may consist of a lead plant with several subordinate ones, or it may be a single plant. Such enterprises have existed in metallurgy, chemicals, textiles, food, and some other branches of industry for many years. The firm (firma) is an early type of production association in which the management of the lead plant serves as the management of a firm consisting of several plants. When a firm is organized no new management structure is set up. Usually the enterprises that make up the firm are located in a single geographical area around a major city. Firms are most often found in the light and food industries.

Today, the "independent" enterprise operates under a principle of economic management known as khozraschet, which is variously translated as self-supporting or economic accountability. In the broadest sense, the term implies that the organization is to operate and be evaluated on the basis of economic criteria. It is expected to cover current operating expenses by revenue from the sale of its output, and to finance internally or by credit a significant part of its capital investment. To reinforce this economic orientation, success indicators for the facility, which determine the size of bonuses for its personnel, are economic, including profitability, sales, and measures of input productivity. Concomitant with the economic orientation, the directors of establishments operating under the khozraschet principle are accorded greater authority to make decisions at the operational level. With the number of official targets specified by middle- and upper-level management organs restricted, as well as the degree of unofficial interference, the focus of decision-making responsibility has shifted downward in Soviet industry, without challenging the ultimate supremacy of the central leadership.

FIGURE 8-12 ORGANIZATION AND MANAGEMENT OF R&D IN AN INDUSTRIAL ENTERPRISE


Director
Chief Engineer--First Deputy Director
Chief Designer
Design Department (Bureau)
Chief Technologist
Technological Department (Bureau)
Laboratories
Chief Mechanic
Department of the Chief Mechanic
Chief Power Engineer
Department of the Chief Power Engineer
Department of Technical Control
Experimental Shop
Department (Bureau) of Inventions and Rationalization

Source: D. M. Gvishiani et al, eds., Osnovnyye printsipy i obshchiye problemy upravleniya naukoy (Moscow, 1973), p. 230.

In general, "factory science" has not been a prominent feature of the Soviet industrial order. Historically, the organizational approach has emphasized the separation of industrial research from production as well as the centralization of R&D forces in institutes designed to serve the needs of the branch as a whole rather than of individual enterprises. Consequently, most enterprises lack adequate in-house R&D facilities. The enterprise-level R&D system of factory laboratories, design offices, experimental shops, and other scientific subdivisions serves primarily the needs of current production. In fact, enterprise scientific subdivisions are not classified under the "science and science services sector" category of economic and social organizations, and their activity is not included in the national plan section for financing research and design work. The organization and structure of technical management within a typical enterprise is presented in Figure 9-12. In many instances, however, the enterprise R&D system does play a vital role in the application of new technology, in the creation of new products and processes, the improvement of product quality or production efficiency, and the maintenance of quality control or technological control of operations.[28]

Associations

Production associations (proizvodstvennyye obyedineniya--POs) and science-production associations (nauchno-proizvodstvennyye obyedineniya--NPOs) are two entities replacing the independent enterprises as the basic units of industrial organization. Eventually, almost all of Soviet industry will be converted to the associational form of management. By the fall of 1976 there were more than 3000 POs in industry. Though they incorporated less than 10 percent of all enterprises, production associations already accounted for nearly 40 percent of total industrial output. At the same time, NPOs--a more selective form of organization--numbered less than 120.

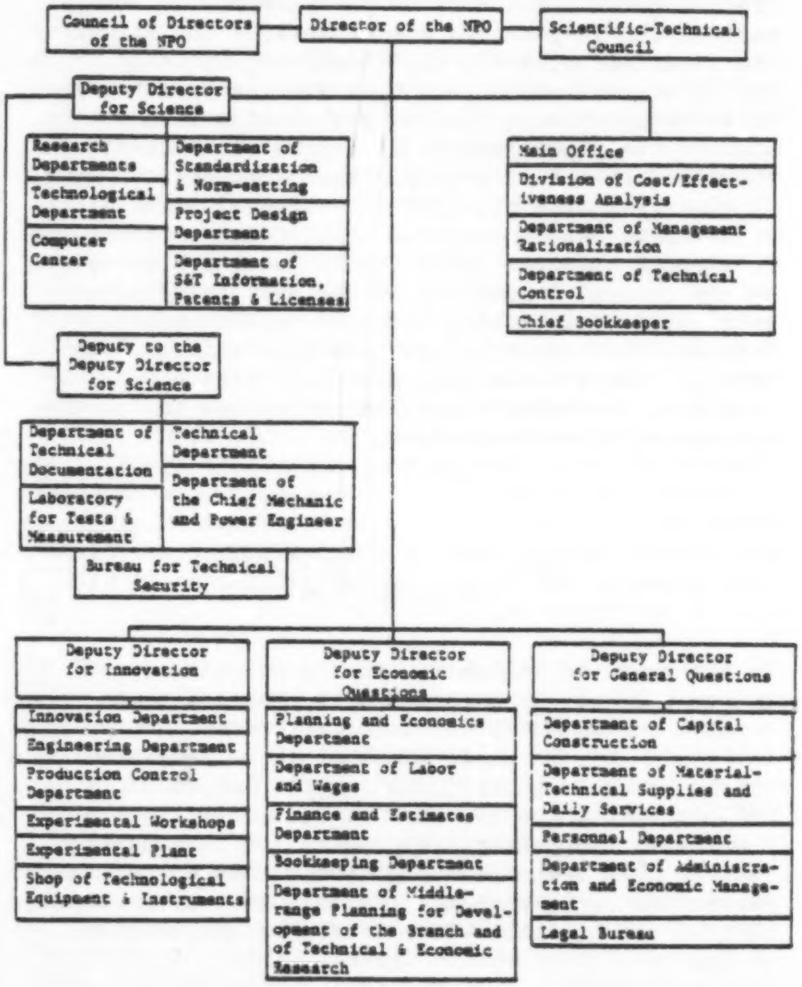
The associations were created in part to accelerate technological progress and to reduce the lead times in the implementation of new technology. Therefore, both the PO and NPO forms may include institutes and design bureaus. In the production association, scientific organizations are usually of local significance and confine their research-development-innovation activity primarily to the production needs of the association. In the NPO, on the other hand, these units are expected to conduct general-purpose or branch-wide R&D, developing innovations for the branch as a whole. The "head" organization also differs. While this role belongs to an industrial enterprise in the production association, it is performed generally by a powerful research institute in the science-production association.

The NPO fulfills the functions of a branch scientific-technical center. Its chief task is to create and apply new technology within the shortest possible time. It is not predominantly a producing organization but is intended primarily to carry out R&D on new products and processes. Ideally, when a new product has been brought successfully through its first production runs by an NPO, the mass production of the article is taken up by the production associations. In line with their concern for the entire research-to-production cycle, several NPOs have special start-up plants and installation units which assist other production facilities in introducing and debugging new technology.

Some NPOs specialize in the creation of new products. Others develop production technology and control systems. Still others concentrate on the development and assimilation of new technological processes. Among the most important tasks of NPOs are reported to be the installation and adjustment of new technology, the conduct of patent/license work, the maintenance of S&T information services, the forecasting of new product demand, and the development of estimates of labor and materials requirements.

In internal organization and management the associations exhibit a range of alternative formats. The degree to which the enterprises in a production association lose their autonomy varies widely. For ex-

FIGURE 8-13 MANAGEMENT STRUCTURE FOR A TYPICAL SCIENCE-PRODUCTION ASSOCIATION (NPO)


Council of Directors of the NPO
Director of the NPO
Scientific-Technical Council
Deputy Director for Science
Research Departments
Technological Department
Computer Center
Department of Standardization & Norm-setting
Project Design Department
Department of S&T Information, Patents & Licenses
Main Office
Division of Cost/Effectiveness Analysis
Department of Management Rationalization
Department of Technical Control
Chief Bookkeeper
Deputy to the Deputy Director for Science
Department of Technical Documentation
Laboratory for Tests & Measurement
Technical Department
Department of the Chief Mechanic and Power Engineer
Bureau for Technical Security
Deputy Director for Innovation
Innovation Department
Engineering Department
Production Control Department
Experimental Workshops
Experimental Plant
Shop of Technological Equipment & Instruments
Deputy Director for Economic Questions
Planning and Economics Department
Department of Labor and Wages
Finance and Estimates Department
Bookkeeping Department
Department of Middle-range Planning for Development of the Branch and of Technical & Economic Research
Deputy Director for General Questions
Department of Capital Construction
Department of Material-Technical Supplies and Daily Services
Personnel Department
Department of Administration and Economic Management
Legal Bureau

Source: A. I. Bogdanov, Problemy upravleniya nauchno-tekhnicheskim progressom: obzor (Moscow, 1977), p. 54.

ample, in the Leningrad Optical-Mechanical Association the general management of the PO fully replaces the plant managements. At the Svetlana Association each enterprise retains a measure of autonomy, and only the basic management functions are centralized. The management of the PO is the same as the management of the largest and most modern of the plants in the association, i.e., the "head" organization of the PO. The other plants are organized as branches of this leading plant. At the Elektrosila Association some of the plants are fully merged with the PO, whereas others have retained some autonomy. A similar pattern of structural diversity also characterizes the science-production associations. According to a model organizational statute on the NPO, issued by the central leadership at the end of 1975, however, all units joining the association lose their independence. Nonetheless, practice continues to diverge from this uniform pattern. Figure 9-13 illustrates the model management structure for a science-production association.

THE ORGANIZATIONAL SYSTEM: WHOLE AND PARTS

The previous discussion of the organization of R&D in the USSR suggests certain features and themes that deserve emphasis. Most basic, of course, is the formal design of the whole edifice for science and technology as an "organizational system" of multiple and well integrated parts, with elaborate but generally internally consistent assignments and responsibilities. This image of a highly centralized and coordinated Soviet system that is able to pursue comprehensive and coherent S&T policies often prevails abroad.

The image, however, conceals as much as it reveals. Though highly centralized, the organizational structure of Soviet science and technology is far from monolithic. On the contrary, it is highly fragmented. An official at the top feels sometimes, in fact, that he sits at the apex of an "inverted pyramid," that the vast bulk of decisions and actions are beyond his influence, much less his control.

Among the prominent structural properties of the system is the segregation of activities by level in the respective hierarchies. Although there are exceptions to the general pattern, the focus of planning and managerial responsibility is centered at three levels: (1) all-union or national; (2) branch or ministry, Academy, or republic; and (3) performer organization (research, design, educational, and production establishment). When a republic organization or element of local industry is involved, a fourth or fifth level of planning responsibility may be interjected accordingly, but in general the three enumerated levels designate the three types of relevant plans. For example, while republic councils of ministers are subordinate to the USSR Council of Ministers, their plans have similar orientation and format. There is similar correspondence in the branch plans at the union and republic levels of a union-republic ministry, although the superior-subordinate relationship is clear, with plans at the subordinate levels incorporating directives of the superior level.

There is a clear intent to delineate organizationally line (or administrative) and staff (or functional) activities at each of the three levels. Certain organs, such as the ministries, are responsible administratively for all activities of a subset of economic and technical establishments, usually in a particular industry. Other organs, such as the state committees, are responsible for at least the formulation and monitoring of a functionally oriented set of policies for all Soviet establishments. The distinction is carried through to the branch and performer organization levels as well. Within the ministry and performer organizations, certain administrations, departments, or individuals are responsible for overall performance of the organization as a whole or for particular subdivisions, whereas planning, finance, supply, and other departments manage their respective functions for the organization as a whole. The distinction between line and staff functions in the academies of sciences is somewhat less clear, due in part to their relative autonomy which in turn is related to the nature of fundamental research. The academies themselves conduct a relatively large share of the planning and other functional activities for their subordinate facilities, although academy facilities are also subject to the policy formulated by the various specialized state committees and, overall, by the GKNT.

Within this context the three principal central management agencies which are concerned with R&D planning and administration are the GKNT, the USSR Academy of Sciences, and Gosplan. Of these, the GKNT's functions may be described as comprehensive, incorporating overall managerial responsibility for Soviet S&T policy and particular concern with inter-branch coordination problems and with facilitating integration between academy, university, and industrial R&D. The Academy and Gosplan are more specialized, concentrating respectively on fundamental research and on industrial R&D and technology utilization. They, in turn, are more heavily involved in operational management in their respective areas, either by formal administrative responsibility in the Academy's case or by the significant de facto authority of Gosplan in managing the economic and technical activities of industrial establishments. The three organs jointly issue many position or policy statements setting forth regulations and guidelines on one or another aspect of R&D planning and management.

In general, the basic principles which underlie the organizational structure also tend to undermine its "systemic" character and cohesiveness. The key to effective organization in the Soviet Union, just as in the United States, lies not in structure but in relationships between individuals and institutions. With parts but no couplings between the parts there can be no system. The traditional design principles of extreme functional specialization by organizations and of institutional dissociation have created structural barriers rather than bonds between the various organizational actors at all levels of the Soviet S&T establishment. As we have seen, the structure of decision making is predominantly vertical and thus substantially inhibits lateral communication, cooperation, and coordination.

Similarly, structural features help create and reinforce functional autonomy and non-integrative attitudes among the organizational parts to the detriment of the whole. With parts and no common purpose there can be no coupling and no system. Soviet authorities naturally intend that the various organizations and agencies complement each other in pursuit of objectives specified by the leadership. In practice, however, the parochial aims and special interests of the parts frequently prevail over the centrally defined purposes and needs of the nation or "system" as a whole. Soviet organizations have been built largely on the principle of total or near total self-sufficiency. Each ministry is an empire of its own, operating almost independently of the others. Each of the central administrative and functional agencies has acquired entrenched bureaucracies which compete with and frustrate each other. The very structure and nature of the R&D administrative system--with its emphasis on multiple authorities, mixed sovereignties, and incomplete functional mandates--inevitably exert their influence on the policy process and on performance. Though of a different kind perhaps than exists in the United States, bureaucratic politics--with all the realities of interagency power, clashes of priorities, and conflicts of interests--nonetheless is a prominent and permanent feature of the "organizational system" for science and technology in the USSR. It is no accident that better "linkage" and "integration" are important organizational issues in Soviet science policy today.

FOOTNOTES

1. G. A. Dorokhova, "Sovershenstvovaniye sistemy organov upravleniya naukoy," *Sovetskoye gosudarstvo i pravo*, 6 (1972), p. 60fn.

2. M. I. Piskotin, V. A. Rassudovskiy, and M. P. Ring, eds., *Organizatsionno-pravovyye voprosy rukovodtsva naukoy v SSSR* (Moscow: Nauka, 1973), p. 141.

3. US-USSR Joint Working Group in the Field of Science Policy, Subgroup 1--Planning and Management of Research and Development, "USSR Short Answers to US Questions Relating to USSR Research and Development Planning and Management," Washington, D.C., National Science Foundation, February 20, 1976, pp. 3-4.

4. *Ibid*., pp. 4-5.

5. *Ibid.*, pp. 12-14.

6. Dorokhova, "Sovershenstvovaniye sistemy organov upravleniya naukoy," pp. 64-65; Piskotin et al, *Organizatsionno-pravovyye rukovodstva naukoy v SSSR*, pp. 187-192, 205. It is not surprising that the idea of creating state committees for science and technology in various republics, modeled after the Moscow body, has been urged and discussed, apparently at the highest levels. See Dorokhova, "Sovershenstvovaniye sistemy organov upravleniya naukoy," p. 65. There is a state committee for science and technology in Georgia, but it is subordinate to the Georgian republic Council of Ministers, not to the USSR GKNT.

7. For example, the USSR State Committee on Inventions and Discoveries is "predominantly oriented to regulating the initiatives and proposals coming from below." Only 30 percent of its recommendations are accepted by the ministries and departments. See Ye. Artemyev and L. Kravets, *Izobreteniya--novaya tekhnika--upravleniye* (Moscow: Ekonomika, 1974), pp. 63, 179-180. Another Soviet critic similarly notes that

the state committee does not possess the authority and means necessary to fulfill its functions. See A. A. Podoprigora, Pravovyye voprosy sozdaniya i vnedreniya novoy tekhniki (Kiev, 1975), p. 85. In drawing up the annual economic plan for 1975 the State Committee on Inventions and Discoveries recommended that 90 inventions and innovations be adopted but the ministries accepted only 9 or 10 percent. See G. Alekseyev, "The Effect Derived from Production," Pravda, September 13, 1976.

8. Dorokhova, "Sovershenstvovaniye sistemy organov upravleniya naukoy," p. 61. For a more detailed discussion of the GKNT, see the excellent study by Louvan E. Nolting, The Structure and Functions of the USSR State Committee for Science and Technology, U.S. Bureau of the Census, Foreign Economic Reports, No.   (Washington, D.C., 1979).

9. Zaleski et al, Science Policy in the USSR, p. 54.

10. B. F. Zaitsev, "Struktura organov upravleniya naukoy i tekhnikoy v usloviyakh nauchno-tekhnicheskoy revolyutsii," in Organizatsiya upravleniya (Moscow, 1975), p. 36 and V. Disson, "Primeneniye programmno-tselevogo metoda pri reshenii nauchno-tekhnicheskikh problem," Planovoye khozyaystvo, 7 (1977), p. 82.

11. "USSR Short Answers," pp. 5-7.

12. Ibid.

13. Ibid., p. 8.

14. Zaleski et al, Science Policy in the USSR, pp. 83-88.

15. V. A. Rassudovskiy, Gosudarstvennaya organizatsiya nauki v SSSR (Moscow: Yuridicheskaya literatura, 1971), p. 30 and G. T. Prokhotskiy and V. G. Khryachenko, Effektivnost raboty nauchno-issledovatelskikh organizatsii (Minsk, 1973), p. 31.

16. "USSR Short Answers," p. 8.

17. Ibid., p. 7.

18. Louvan E. Nolting, The Financing of Research, Development, and Innovation in the USSR, By Type of Performer, U.S. Department of Commerce, Foreign Economic Reports, No. 9 (Washington, D.C., 1976), pp. 3-4.

19. A. I. Shcherbakov, Sotsialno-ekonomicheskiye problemy effektivnosti nauchnogo truda (Novosibirsk, 1975), p. 48.

20. V. I. Duzhenkov, "Problemy territorialnoy organizatsii nauchnoy deyatelnosti," in Problemy deyatelnosti uchenogo i nauchnykh kollektivov (Moscow-Leningrad, 1977), VI, pp. 48-49.

21. "USSR Short Answers," pp. 42-45.

22. I. D. Ivanov, "Preodoleniye prepyatsviy i stimulirovaniye pri vnedrenii novoy tekhniki i novykh metodov upravleniya" (Overcoming Obstacles and Improving Incentives in the Introduction of New Technology and New Methods of Management"), p. 20. Soviet Side of the Joint US-USSR Subgroup on Planning and Management of Research and Development. Unpublished (draft) paper, 1976; V. G. Shorin and A. A. Popova, "Organizatsiya nauchnoy raboty v vuzakh," in Gvishiani et al, Osnovnyye printsipy i obshchiye problemy upravleniya naukoy, p. 200.

23. Ibid., pp. 203-204; Nolting, The Financing of Research, Development, and Innovation in the USSR, pp. 13-14.

24. Ibid., p. 8.

25. Ibid.

26. Ibid., pp. 8-9; Zaleski et al, Science Policy in the USSR, pp. 406-408, 541-546.

27. "Shorin and Popova, "Organizatsiya nauchnoy raboty v vuzakh," p. 203.

28. Nolting, The Financing of Research, Development, and Innovation in the USSR, pp. 14-15.

IX THE FORMULATION OF R&D PLANS AND PROGRAMS

OVERVIEW OF SCIENCE AND TECHNOLOGY PLANNING

Plans in the Soviet Union are the fundamental instrument for integrating and controlling production activities of all kinds and at all levels of aggregation, ranging from the state as a whole through a variety of economic units to the individual. By assuming this burden, plans must be not only directive, conveying the wishes of the leadership, but also sufficiently informative on factors external to the planning unit to permit effective coordination. Plans must also incorporate a system of incentives and penalties to insure the accomplishment of assigned tasks.

By its very nature, R&D seems incompatible with this type of planning. Optimally, plans predetermine results, while R&D in varying degrees involves exploration of unknown or uncertain territory. Problems of uncertainty and risk are particularly great at the fundamental research stage and subside increasingly with movement toward the development end of the R&D spectrum and the more deterministic world of production. In general, this factor is recognized in Soviet science policy. Larichev, for example, notes that "formulation of the goals of planning depends substantially on the means of determining with a sufficient degree of certainty the expected final results of R&D."[1] Because of the difficulties of predicting and evaluating R&D results, their aggregation is also appreciably harder than the aggregation of production targets. Indeed, until well into the 1950s activities under research, development, and innovation in the USSR were seen as "too complex and numerous and the results too unpredictable and indefinite to be worth the effort of joining them into a single coherent plan."[2] For that matter, R&D was still re-

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garded as being too aloof from general economic problems and processes to permit any convergence of science policy with economic policy.

Increasingly, however, the planning of science and technology has become a separate and consolidated activity in the Soviet Union, especially since the late 1960s. Like the basic approach to organization and structure, the orientation in planning is to treat the research-to-production cycle as a single complex of activity integrated along highly formal and hierarchical lines. Containing a variety of individual and sequential components that together constitute an integrated unit, the R&D plan itself is but one element of a larger plan governing all aspects of production activity. In the State Plan for the Development of the National Economy, the chapter incorporating the Plan for the Development of Science and Technology is accompanied by chapters devoted to planning sectoral development (including industry, agriculture, transport and communications) and capital construction, as well as to planning functional areas, such as labor and manpower, various financial indicators, and foreign trade. There are similar collections of targets at all plan levels, and each collection for all types of indicators in principle is mutually reinforcing and internally consistent.

Figure 10-1 demonstrates the interrelatedness of the separate features of the various plans as well as the hierarchical structure of plans described in chapter 9. At the national level, S&T problems are clearly one of the several types of national problems. The problem orientation of the plans must be rendered consistent with the task of establishing the appropriate "proportions" in the national economy, or in other words, ensuring that sectoral and regional development is proceeding as intended and that the plan as a whole is internally consistent. At the intermediate level, the task of reconciling plans with different orientations--branch of the national economy or industry, program, and geographical region--is illustrated. At the level of the performing organization, the establishment generally must be responsive to the

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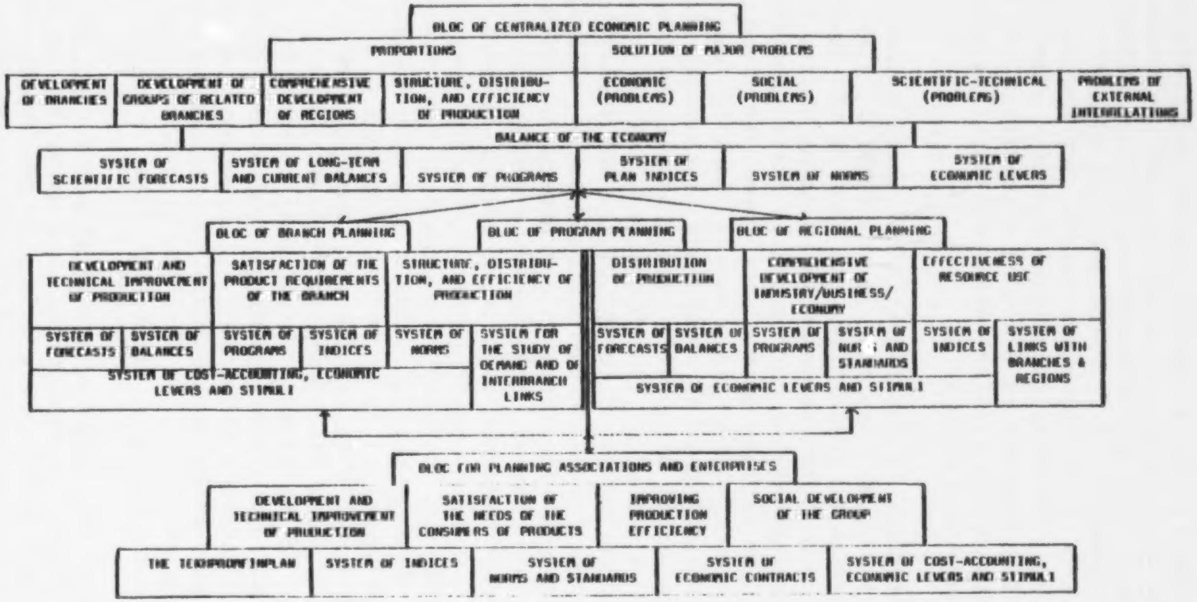
FIGURE 9-1 OVERVIEW OF THE CONTENT AND NETWORK OF SOVIET ECONOMIC PLANNING


BLOC OF CENTRALIZED ECONOMIC PLANNING
PROPORTIONS
SOLUTION OF MAJOR PROBLEMS
DEVELOPMENT OF BRANCHES
DEVELOPMENT OF GROUPS OF RELATED BRANCHES
COMPREHENSIVE DEVELOPMENT OF REGIONS
STRUCTURE, DISTRIBUTION, AND EFFICIENCY OF PRODUCTION
ECONOMIC (PROBLEMS)
SOCIAL (PROBLEMS)
SCIENTIFIC-TECHNICAL (PROBLEMS)
PROBLEMS OF EXTERNAL INTERRELATIONS
BALANCE OF THE ECONOMY
SYSTEM OF SCIENTIFIC FORECASTS
SYSTEM OF LONG-TERM AND CURRENT BALANCES
SYSTEM OF PROGRAMS
SYSTEM OF PLAN INDICES
SYSTEM OF NORMS
SYSTEM OF ECONOMIC LEVERS
BLOC OF BRANCH PLANNING
BLOC OF PROGRAM PLANNING
BLOC OF REGIONAL PLANNING
DEVELOPMENT AND TECHNICAL IMPROVEMENT OF PRODUCTION
SATISFACTION OF THE PRODUCT REQUIREMENTS OF THE BRANCH
STRUCTURE, DISTRIBUTION, AND EFFICIENCY OF PRODUCTION
SYSTEM OF FORECASTS
SYSTEM OF BALANCES
SYSTEM OF PROGRAMS
SYSTEM OF INDICES
SYSTEM OF NORMS
SYSTEM FOR THE STUDY OF DEMAND AND OF INTERBRANCH LINKS
SYSTEM OF COST-ACCOUNTING, ECONOMIC LEVERS AND STIMULI
DISTRIBUTION OF PRODUCTION
COMPREHENSIVE DEVELOPMENT OF INDUSTRY/BUSINESS/ECONOMY
EFFECTIVENESS OF RESOURCE USE
SYSTEM OF FORECASTS
SYSTEM OF BALANCES
SYSTEM OF PROGRAMS
SYSTEM OF NORMS AND STANDARDS
SYSTEM OF INDICES
SYSTEM OF LINKS WITH BRANCHES & REGIONS
SYSTEM OF ECONOMIC LEVERS AND STIMULI
BLOC FOR PLANNING ASSOCIATIONS AND ENTERPRISES
DEVELOPMENT AND TECHNICAL IMPROVEMENT OF PRODUCTION
SATISFACTION OF THE NEEDS OF THE CONSUMERS OF PRODUCTS
IMPROVING PRODUCTION EFFICIENCY
SOCIAL DEVELOPMENT OF THE GROUP
THE TEKHPROMFINPLAN
SYSTEM OF INDICES
SYSTEM OF NORMS AND STANDARDS
SYSTEM OF ECONOMIC CONTRACTS
SYSTEM OF COST-ACCOUNTING, ECONOMIC LEVERS AND STIMULI

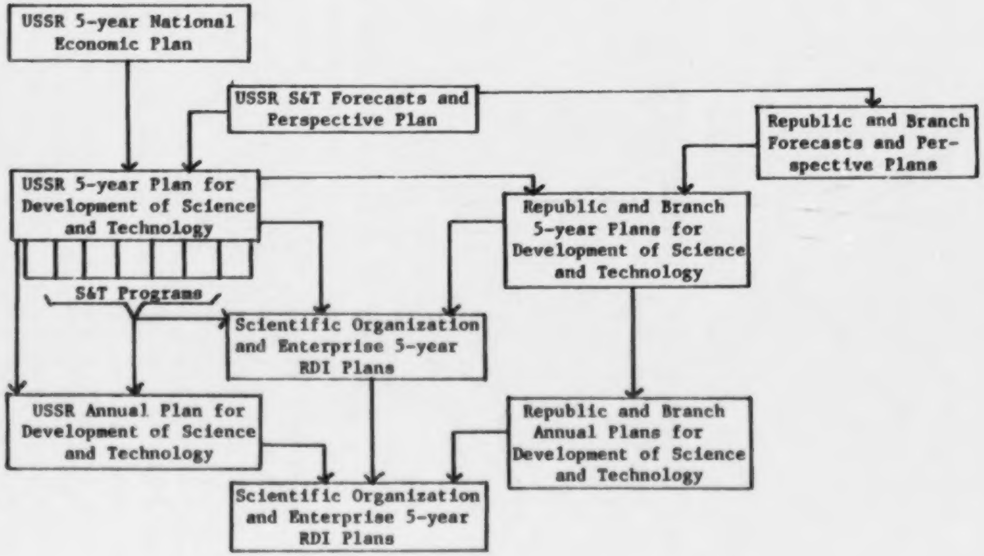
Source: V. M. Ivanchenko, Metodologiya narodnokhozyaystvennogo planirovaniya (Moscow, 1975), p. 47.

demands of each of the intermediate level plans. At all levels, the economic, technical, and social objectives imposed upon the planning unit are alike, accounting for the generally similar structure of the plans at each level. In addition, the mechanisms for plan expression and enforcement, such as indicators, norms, standards, and incentives, are similar at all levels. It is by these mechanisms that the state committees and other functional agencies generally impose requirements on planning authorities and thereby relate to the vertical and administrative orientation shown in Figure 10-1.

In addition to the hierarchical and functional segregation of plans depicted in Figure 10-1, plans are also segregated temporally. At each of the levels and by each of the responsible planning units, plans are formulated which correspond to three time frames: perspective or long-term plans; five-year plans; and annual plans. Long-term plans are largely forecasts of alternate trends in science and technology and in the development of specific new products and processes over a period of from 5 to more than 20 years. Perspective plans and forecasts are not really binding or operational documents; they serve primarily as guidelines to orient economic strategy and science policy. In general, the five-year and annual plans incorporate relevant targets specified, respectively, in the long-term and five-year plans, and they are also made more "concrete" or detailed. In recent years, the five-year plan has become more important than the annual plan, as authorities have placed increased emphasis on careful and comprehensive formulation of goals over longer periods in order to concentrate resources more effectively on priority projects and to provide greater direction and control over the nation's R&D effort. The connection between the various kinds of R&D plans, segregated by administrative hierarchy, by function or program, and by duration of operation, is illustrated in Fugure 10-2.

Despite the very formal and all-embracing character of plans, the analytical base underpinning science policy and planning is weakly developed. Advances in conceptualization of the R&D process have gen-

FIGURE 9-2 STRUCTURE OF SOVIET RESEARCH, DEVELOPMENT, AND INNOVATION PLANS AND FORECASTS


USSR 5-year National Economic Plan
USSR S&T Forecasts and Perspective Plan
Republic and Branch Forecasts and Perspective Plans
USSR 5-year Plan for Development of Science and Technology
Republic and Branch 5-year Plans for Development of Science and Technology
S&T Programs
Scientific Organization and Enterprise 5-year RDI Plans
USSR Annual Plan for Development of Science and Technology
Republic and Branch Annual Plans for Development of Science and Technology
Scientific Organization and Enterprise 5-year RDI Plans

Source: Louvan E. Nolting, The Planning of Research, Development, and Innovation in the U.S.S.R. (Washington, D.C., 1978), p. 23.

erally lagged. Such notions as "innovation process," "technology transfer," and "commercialization cycle," which figure prominently in Western writings, are relatively unknown in the USSR. Soviet analysts, on the contrary, tend to use terms like "research-production cycle," "scientific and technological complex of work," and "complex of preproduction work" to describe the sequencing, organization, and stimulation of scientific R&D. For the most part, their concepts have revolved around phase-dominant models of innovation with emphasis on separate functions and individual work efforts performed in isolation from one another and cut off from the application of results into production. Only recently have they begun to take a more process view of innovation with the focus on final results and overall integration.

Also only recently has a predominantly linear-causal view of innovation been called into question. This model emphasizes a relatively simple and orderly forward flow of work from theoretical conception to practical use. The notion that innovation involves a complex and helix-like stream of events and stages with significant feedback coupling is not commonly held. Accordingly, various stages of work are planned predominantly in sequence rather than simultaneously and in parallel. The result is significant losses of time between different phases and a lengthening of the process as a whole.[3]

Though important strides have been made in reconceptualizing R&D and in moving toward a more sophisticated analytical base for deciding problems of scientific choice, deficiencies remain. As two experts on R&D note, "a number of questions in this complex process have not yet been studied, and some have not even been posed in the literature."[4] There is still considerable ambiguity and inconsistency among Soviet writers who describe and label the stages of the R&D cycle. "No official methodological instructions by Gosplan or the Central Statistical Administration are available which delineate the precise stages," Nolting points out. Moreover, he adds, the conceptual division of stages is not necessarily followed in planning, financing, and reporting of R&D. The basis for planning and financing remains primarily the "institutional performer," not the stages of the research-to-production cycle.[5] Again the heavy organizational bias of the system is evident. Planning and the allocation of resources are organized mainly around institutions rather than projects and programs.

Furthermore, R&D has been perceived and planned in rather narrow terms and time frames. The planning process has usually ended with the creation of experimental prototypes or at best with small batch production of new products. The actual introduction of R&D results has been beyond the boundaries of science planning. The focus has been on building up scientific and technological "potential." The Russian word for the latter, zadel, means literally a stock of semi-finished articles waiting to be processed. A short time horizon, usually only a year, has also prevailed. Only since the late 1960s has attention been given to developing the concept of scientific and technical progress, to elaborating its meaning and implications for both the research sector and the industrial sphere, and to making it the object of planning. Such an extension of the boundaries of planning complicates the task considerably. V. Yu. Budavey and M. I. Panova observe, "The essence of the matter is that the problem involves drawing up not just a separate section of the national economic plan but a second plan." Yet, they add, "Without global evaluations of scientific and technical progress for the long term it is impossible to work out a strategic planning policy in this area and to determine correctly the tasks of a uniform technology policy."[6] No uniform conception of the future shape of science, technology, or of the economy has emerged to guide the planners, however.

Science policy analysis and planning still suffer from inadequate indicators, norms, and information. By 1974 nearly 300 different indicators were used that directly or indirectly characterized scientific and technical progress. However, they did not form a sufficiently goal-oriented system of indicators to insure the integrated planning of science, technology, and economic growth. In addition, their application was usually not concerned with the planning and evaluation of production efficiency.[7] Scientifically-based norms are still lacking for financing research and for supplying it with human and material resources. Norms governing the performance of R&D are absent, as are norms regulating the length of projects and their stages. When schedules are included in planned assignments, they are often fixed arbitrarily without any sufficient basis.[8] Nobel laureat and Academician Kantorovich noted in 1976 that "in practice consideration of the time factor is not systematic and is frequently non-existent" in R&D decision making.[9] Yet, without taking time into account, all Soviet science analysts agree, it is virtually impossible to evaluate any other indicators, such as the technological novelty or economic advantages of an idea. All depend directly on "time," on how rapidly scientific ideas move from the laboratory into use.

Serious deficiencies also exist in the data base for planning and evaluating R&D. Decision makers are frequently faced with fragmentary and contradictory information. Statistics on expenditures for fundamental research, for applied research, and for development are not regularly collected and reported. The absence of standard concepts for various stages and categories of R&D results in unsystematic information and conflicting calculations. The information gap is particularly glaring with respect to expenditures for innovation and the introduction of new technology. Since most R&D units at industrial enterprises and associations are not formally classified as "scientific institutions," statistics on R&D performed at production establishments are not systematically gathered, nor are they included in "official" science allocations. The lack of accounting and reporting of these expenditures seriously "hampers the objective measurement of inputs on scientific and technical progress," note S. Golosovsky and G. Yeremenko.[10] Essentially, the later stages of the research-to-production cycle fall outside--or, more accurately speaking, "between the cracks" of--the system of planning and control. Finally, a constant flow of operational information is lacking on the course of plan implementation. Information comes at regular reporting periods which may not coincide with the planned completion of projects and tasks. Thus, the information may come too late to permit timely corrective action.[11]

It is also important to note that the "technology" of Soviet planning is still relatively primitive. Simple and semi-intuitive methods of evaluation and manual calculations predominate. The inadequacy of technique becomes all the more apparent in the light of the increasing scale and complexity of the task it must tackle. In preparing the annual plan alone Gosplan works up 47 million indicators. One variant of the national macroeconomic plan requires 83 billion separate calculations. At present nearly four billion documents circulate on various levels of the planning and management hierarchy. Within industrial enterprises, associations, and other economic organizations almost five billion work orders and more than two billion supplementary requests are formulated each year.[12] The head of the Main Computer Center at the USSR Gosplan reported with some pride that about 20 percent of the Tenth Five Year Plan (1976-1980) was prepared on the basis of computer techniques.[13] On the eve of the 1980s the pocket calculator has not yet arrived in the Soviet Union, and the dominant tool at hand remains the abacus. "It is no accident," observes Boris Milner, now of the Institute for Systems Studies, "that a serious contradiction has developed between the growth of the volume of information and the traditional methods of data collection and processing."[14]

The need for more "science" in R&D planning and management is generally recognized among Soviet authorities today. Defects in the conduct of analytical work in scientific organizations are decried at all levels of the planning ladder.[15] Special attention is being given to enhancing integrative capabilities, both analytical and administrative, of central decision makers to formulate comprehensive and coherent policies. Accordingly, interest is increasing of late in developing and applying the modern tools of systems planning and management and more sophisticated decision aids in this area. Indeed, "systems analysis" and "the systems approach" have become favorite terms as the regime seeks to build a more effective conceptual framework for R&D problem-solving.

These underlying aspects of S&T planning are important to note at the outset, because the formal structure and procedures of planning tend to dominate Soviet discussions of science policy and sometimes overshadow these dimensions, which not only impact upon the structure but, more importantly, influence appreciably the quality of R&D decision making.

RESOURCE PLANNING AND ALLOCATION FOR RESEARCH AND DEVELOPMENT

In a centrally planned economy like that of the Soviet Union, control over real resources, and not merely the availability of funds, is the essential prerequisite for the conduct of R&D.[16] In other words, work undertaken at the initiative of the performing or sponsoring organization depends in large part upon whether the activity itself and the expected capital, labor, and material inputs are each accounted for in respective plan chapters. Ruble values serve as the principal means of measuring and aggregating performance, but in most cases it is not possible to bid resources away from other organizations as a means of expanding the scope of work. At the least, then, funding serves as an essential if passive indicator of the magnitudes of various categories of R&D. Whether funding can serve as an active control mechanism, furnishing command over real resources, is a function of the level of aggregation of the decision, the specific fund and/or organization involved, and the priority and nature of the research.

While characteristics of the "concrete" project may predominate in decision making at the level of the performer organization, with funding a secondary consideration, high-level decision making in practice cannot be made entirely dependent on a careful study and aggregation of the characteristics of specific projects. At the highest level, when estimating the total share of national income and determining the total share of the state budget which will be devoted to science, the Council of Ministers must consider not only the potential for scientific advance in necessarily broad categories of research and development but also the impact of expanded technical advances on economic and social developments.[17] The growth rate of expenditures on science is generally set somewhat higher than the growth rate for national income and industrial production to insure scientific and technical progress.[18] Indeed the very rapid and sustained rise in total official Soviet allocations for science, equal to 2.4 billion rubles in 1958 and 17.4 billion rubles in 1975, is indicative of the leadership's awareness of the growing relative importance of technological development as a factor contributing to economic growth.

The sum allocated to science, as well as its intended breakdown by user category and purpose, is specified in a chapter of the annual and five-year State Plans for Development of the National Economy. Here the total volume of outlays for scientific research projects and the sources of financing are stipulated, along with the overall wage fund for workers at scientific institutions.[19] These indices, in effect, determine the extent of money, manpower, and materials for conducting R&D. Provisions for capital investments for the construction, expansion, and renovation of scientific facilities are also included in another chapter of the macroeconomic plans as part of the total volume of capital investments for the development of various sectors of industry and the economy.[20] The science expenditure plans are formulated by the GKNT in collaboration with Gosplan, the Academy of Sciences, and the Ministry of Finance, on the basis of proposals submitted by the USSR ministries and departments as well as the union republic councils of ministers. The plans emphasize, then, both the association of financial and real resources and the relationship of broad aggregates to the recommendations of intermediate level management organs and institutional subsystems.

There are two broad sources of financing R&D: (1) the State Budget and (2) the fiscal resources at the disposal of ministries and agencies at the intermediate level and of enterprises and scientific organizations at the performer level. In Soviet terminology the second source is designated "own funds." Most own funds are, in fact, centralized by the ministry that administers them. Only a portion are decentralized and used directly by enterprises and organizations to contract for R&D with scientific institutions.[21] The amount of these resources for each ministry and agency is stipulated in the plan for financing scientific research projects as a source of financing.

Slightly less than one-half of all science expenditures is financed by the State Budget. Budgetary allocations encompass, first, R&D aimed at solving national priority or so-called "basic scientific and technical problems" specified in the macroeconomic plan. These "basic problems" are usually interbranch, involving the joint efforts of multiple ministries and agencies. The State Budget also finances research in the natural and social sciences as well as R&D projects linked to the solution of the most important branch-wide tasks.

As a rule, State Budget grants are heavily used in the financing of theoretical or exploratory scientific research where R&D results cannot be closely associated with ultimate economic savings. In 1975, for example, 97 percent of expenditures by research institutes specializing in public health, 90 percent of expenditures by those in agriculture, and 80 percent of expenditures by the USSR and republic academies of sciences were financed through the state and republic budgets.[22] These same sources generally seem to fund a much smaller portion of the activities of industrial applied R&D institutes. According to one recent estimate, central budgetary allocations cover, on the average, only about 20 to 25 percent of the work of branch scientific organizations and about 15 percent of the expenditures of industrial enterprises related to "scientific and technical progress."[23]

Budget grants are made directly to the intermediate level management organs--the academies of sciences, the Ministry of Higher and Specialized Secondary Education, the branch ministries, and the GKNT. The size of the grants is negotiated and coordinated by the GKNT. In recent years, about 30 percent of the budgetary allocations for science has been earmarked for the "basic S&T problems," which fall under the general responsibility of the GKNT. The remaining 70 percent has been distributed to the ministries and other major agencies to be used at their discretion. The "discretion" of these organs in distributing the funds--also largely in the form of block grants--to performer organizations depends upon the extent to which the latter's activities are accounted for in the all-union, branch, and republic plans.[24] In such instances, the funds may be "designated" and the intermediate level management organ serves merely as a conduit. Sometimes, the facility itself proposes these projects. In any case the total size of a facility's budget allocation is not likely to fluctuate widely as a consequence of variation in the number and size of projects of all-union and branch importance. In other words, work not accounted for in all-union and branch tasking in total tends to fluctuate in size and accordingly is funded to furnish stability to facility activities.

The experience of the Ukrainian Academy of Sciences in the 1960s illustrates this phenomenon as well as the hierarchical funding procedure:

> At the beginning of each year, the State Committee for Science and Technology negotiates with the Ministry of Finance an overall preliminary sum. On the basis of the proposal

> made by the State Committee, Gosplan fixes a global sum for the Ukrainian Academy of Sciences for the coming year. This sum increases from year to year at a more or less standard rate of four to six percent.
>
> Once the global sum has been fixed, the institutes of the Ukrainian Academy forward their claims to their Division and to the Presidium, which is aided in its deliberation by a special department broken down into a subdepartment for overall planning. The Presidium has a number of other special departments for finance, capital construction, equipment and accounting.
>
> Figures are then prepared for each of the three Sections of the Academy which indicate the provisional sum to be made available to them for equipment and for other expenditures. The Vice President of the Academy, responsible for each section, decides on the distribution of funds among the institutes concerned.[25]

The experience, particularly the virtually automatic increase in annual funding, also demonstrates that budgetary allocations play an important active role at higher levels of aggregation and particularly in Academy fundamental research. There are similar accounts regarding research conducted in higher educational institutions. In the 1960s, Wienert notes, there was no relation between the nature of research projects and the available financial means. Research funds were distributed to the VUZy according to the number of departments.[26] In general, Zaleski concludes that the traditional criteria for allocation are the gross value of work on an historical basis and/or the number of research topics.[27]

Evidence suggests that institutional funding rather than project funding is still the predominant practice in Soviet R&D, as is the tendency toward simple aggregate planning and incremental planning "from the achieved level." P. N. Zavlin and a group of science analysts in Novosibirsk attribute the persistence of these practices to the absence of formal criteria for planning science and allocating resources.[28] The lack of any precise norms has allowed personal influence and establishment reputation to carry undue weight. Dissatisfaction with existing methods causes G. Pospelov, a Corresponding Member of the USSR Academy, to declare, "We must finance not only organizations, enterprises, and associations but also goals and tasks, projects and programs."[29] The system of institutional funding is also seen as a cause of indefinite fixing of responsibility and poor coordination among R&D stages and projects.

Still other Soviet writers point to the contradiction between the conservative structure of expenditures based on financing of immobile scientific organizations and the inherently dynamic character of science.[30] The inertia of existing institutions and ongoing projects is hard to break. Indeed, it is almost impossible, it seems, to "shut off" any unsuccessful program, much less "shut down" an unproductive institution. As A. M. Birman notes, "While providing ostensible regulation and supervision, the present system of financing research allows some institutions to go for years without producing any significant results."[31] At the same time, it is difficult to get new ideas and projects accepted. Mounting concern over these defects of the existing system led to rising emphasis in the 1970s on the need to expand application of a "programmed-goals approach" to planning and financing of R&D. Such an approach oriented toward projects and end results is frequently used in the military and space sectors. Praising this method, Pospelov notes, "The new will not have to 'fight its way up' from below, proving its right to exist. Under such a system of financing, all shoots of the new will be visible from above and can always be given timely assistance."[32] But program planning and zero-based budgeting have not yet become dominant forces in Soviet civilian R&D activities.

To return to the issue of budgetary distribution, industrial R&D conducted within the ministerial system has a heavy component of state and ministry budget financing, but often for a somewhat different reason than at Academy and VUZy facilities. The conduct of fundamental research in the latter establishments renders it difficult to relate research to practical results and link compensation accordingly. Industrial research is generally applied, sometimes narrowly so, creating the potential for direct compensation based on results. The benefits of certain R&D, however, may extend beyond the bounds of the sponsoring and/or performing facility, and in principle this facility should consider such "external" benefits in making its decision to undertake the project. To consider the benefits when the facility is evaluated on the basis of economic performance, a way must be found for the facility to capture a portion of the benefits. In the United States, a facility might achieve this end through patents and subsequent licensing agreements, but legally granted proprietary rights of this type on a facility basis are severely restricted in the USSR. In the Soviet system a State Budget grant is used for this purpose. A case in point is the large project to mechanize production operations at the ZIL automobile plant:

> The program was accomplished at the initiative of the ZIL Association, but taking into account its important national economic value, the State also took part in its financing. Fifty percent of ZIL's expenditures were covered by the State Budget, and fifty percent were covered by profits of the association. The resources of the association which were intended for improvement of current production were not touched (the fund for the development of production).[33]

In general, State Budget grants to industrial facilities are more likely to be tied to such specific projects of "important national economic value" than is the case for Academy and university facilities.

Both at the central and intermediate management level, small but significant reserve funds are retained to finance R&D. The significance of the funds derives from their reserve status and their priority, or, in other words, from the flexible and discretionary way in which they may be used. This is particularly important in an economy where activities and requisite inputs are tautly planned for in advance, as in much centralized funding. The GKNT, for example, retains as a reserve a modest fraction (1.5 to 2 percent) of the annual budget allocation to science. The State Committee can distribute these funds as needs arise during the year for important scientific research work not included in the approved plan. In the period 1971 to 1975, for example, research institutes under the Ukrainian Academy of Sciences completed 354 additional projects for which the GKNT allocated 37 million rubles from its reserve fund.[34] Industrial ministries and other major agencies may also keep at their disposal up to 2 percent of their budget allocations for science for special use. The "active" role of such funds is bolstered by their high priority, especially in the case of the GKNT fund. They are able to command real resources at short notice for use in urgent and unanticipated projects.

Financing of R&D at the level of the performer organization, or decentrally financed R&D, is accounted for either by contract with a sponsoring organization or by revenue generated by the performer organization's own economic activity. Research institutes and design bureaus, of course, depend almost entirely upon contract research for this financing, and the importance of contract research in the total financing of their activities is naturally closely related to the extent to which their work is directed at satisfying the requirements of industry. In some ministries, such as those machine-building ministries with a pronounced "systems" or end product orientation (e.g., motor vehicles, aircraft), certain R&D facilities finance the majority of their work on the basis of contracts. In institutes of the academies of sciences contracting naturally is far less significant. For the USSR Academy as a whole, by 1975 about 12 percent of the total work was financed by contract receipts. In the Siberian Division and in the Ukrainian Academy, which have more extensive ties with industry, the share of contract financing had climbed to roughly 20 percent and 38 percent, respectively. In some academy facilities in the Ukraine this figure is much higher. In the Institute for Superhard Materials and the Physico-Mechanical Institute, for example, contracts accounted in 1975 for 69 percent and 70 percent, respectively, of the total work.[35]

The degree of contract financing in university facilities also varies considerably. In some technical schools and departments, the share is extremely high. Overall, in fact, contracts account for about 80 percent of all VUZy R&D. This high share reflects the concentration of VUZy research and development in branch laboratories, which are entirely financed through contracts made with the branch ministries.[36] During the period 1971 through 1975 the volume of R&D financed through the State Budget rose by 38 percent while contract receipts increased by 78 percent.[37]

In the enterprise or production association several sources of funds are available for financing innovation and R&D-related work. These include the Special Fund for Financing Scientific Research of its parent ministry as well as State Bank credits. The largest source of financing is its own special purpose funds: (1) the Unified Fund for the Development of Science and Technology; (2) the Fund for Assimilation of New Technology; (3) the Fund for Development of Production. These funds are used to finance research, development, and innovation conducted both by enterprise scientific subdivisions and by outside performers under contract.[38] In general, Berliner concludes that "the organization of the supply of financial resources for R&D appears to be no problem for the innovating enterprise."[39] The real problem is to create the will to innovate. Human motivation is the commodity in short supply, not material and fiscal resources.

On the whole, financial allotments at this level of R&D tend to be passive. Decisions at the level of the institute, design bureau, enterprise, and association can be related more easily to specific projects and input requirements without the necessity of allocation by lump sum. Similarly, the lesser priority attached to decisions at this level implies that funding is by no means a guarantee that real resources can be commanded if not allotted in production and distribution plans. Thus, the importance and priority of the particular input in question determines the extent to which funding decisions can have an active role, especially at this level.

Taken together, then, these various factors and considerations illustrate that the allocation of financial resources to research and development is an integral feature of Soviet planning. They also demonstrate the predominantly hierarchical nature of financial planning as well as the relative importance of various sources of funding. The degree to which financial mechanisms are an "active" planning control instrument is largely a function of the level and priority of the decision and decision maker.

In addition to these features, a few other basic points about Soviet resource planning and allocation merit brief mention.

First, insufficient attention is given to the utilization of resources. Only since the late 1960s have authorities gradually become aware of constraints on resources and concerned about the effectiveness of their use. However, analytical work is still deficient in this sphere, in large part because the whole system of planning, financing, and management of R&D remains basically input-oriented rather than output-oriented.

A major aim, in fact, of the increased stress on the programmed-goals approach is to help shift the focus of planning, policy, and performance toward end results. "By directly connecting goals and resources, expenditures and output, programming methods of planning create a real basis for objectively evaluating the effectiveness of resource utilization, for choosing rational decisions, and for optimizing interbranch proportions," according to one group of Soviet decision analysts.[40] Academician Fedorenko also describes this as an effective method of "dovetailing goals and resources and of coordinating regional, branch, and programmatic aspects of the plan for the development of the national economy."[41] That is, program planning is regarded by some Soviet writers to be not only a more effective analytical device for problem-solving, but also a better way of allocating resources and balancing expenditures so as to insure the appropriate "proportions," noted earlier in our discussion, between the solution of key national S&T problems and the development of various economic sectors and regions. The preponderant weight of the existing branch approach to planning and financing makes it difficult to concentrate R&D resources on priority interbranch projects, to eliminate waste, and to accelerate innovation.

Second, the State Budget in the Soviet Union is an annual budget. There is no five-year budget that can be linked to the five-year macroeconomic plan. Funds--as the basis for obtaining material and technical resources--are distributed only for one-year periods. Such a short time horizon prevents the development of a genuine investment mentality toward R&D outlays that is oriented to long-term returns. On the contrary, it reinforces the dominant tendency to plan "from the achieved level" and to focus on inputs rather than results. Since unspent funds revert back to the budget, there is a strong tendency for R&D performers to use up all resources and thus "zero out" at the end of the year. There is little incentive to reduce expenses and to economize on materials and labor under the existing system.

Third, there is the problem of coordinating financing with material and technical supply. In principle, each financial flow is to be matched by a corresponding physical flow, and whenever possible both are to be planned. In practice, however, the linkage rarely works smoothly and rapidly, and sometimes it is not made at all. Part of the problem is that R&D organizations frequently cannot anticipate their requirements for materials, equipment, and scientific instruments, and some delays are unavoidable. But the main trouble lies in the notorious inefficiencies of the Soviet supply system. Supply needs are not automatically met through the allocation of financial resources or through inclusion of R&D targets into the S&T plans. Instead, these requirements are written into the Plan for Material Supplies which is a separate chapter of the state economic plan but not always well integrated with it.[42] If an item is not included in the supply plan its procurement is always protracted, if not impossible. This is especially true for R&D facilities at production establishments which lack priority status on the distribution list. In general, though, scientific and engineering supplies are scarce. Not only modern sophisticated hardware but even simple articles, like test tubes and measuring jars, are hard to come by. The whole scientific instruments industry in the USSR is still backward and undeveloped.

In recent years, several steps have been taken to remedy the supply problems of R&D organizations. Seventy Moscow research institutes and design bureaus belonging to 13 different ministries have been transferred--on an experimental basis--to nonallocated supply status for the entire so-called "interministry itemized list" of some 25,000 products through the wholesale trade system. These facilities can apparently now satisfy their supply needs much more quickly than before.[43]

Efforts have also been made to expand the circulation and use of scarce equipment through the introduction of a rental supply system on a limited regional basis. At some R&D centers expensive measuring or testing devices sit around in warehouses after being used only once. Equipment and instruments pile up in labs. Meanwhile, other organizations with less political influence or professional prestige, like the VUZy, plant labs, and design bureaus, are unable to acquire the necessary apparatus and scientific supplies to conduct their R&D projects. This is in part due to defects in amortization procedures for scientific equipment. A more important factor, however, is that scientific institutions have engaged in much the same kind of hoarding practices as industrial enterprises. They are reluctant to share, much less give up, valuable and scarce resources, even if they do not use them. The establishment of a rental system is a means by which to free the quantity of little used, highly expensive, greatly needed, but essentially "frozen" equipment that is growing at an appreciable rate. It represents a device by which to break down some of the institutional barriers between the "haves" and the "have nots," to bring together the demand of some organizations and the supply of others.

Suffice it to note that in the early 1970s the rental of scientific instruments and lab equipment began to be organized, initially in the Leningrad region. Plans have been worked out to develop such rental services in a number of major scientific centers throughout the USSR, such as Moscow, Minsk, Tbilisi, Kiev, and Irkutsk. Along with filling one-time orders, the servicing of customers on the basis of long-term contracts has begun to be practiced. Rental arrangements sometimes involve the provision not only of equipment and supplies but also of important services, such as testing and measurement. This is particularly important for extremely complex and costly instruments, which can be easily damaged if not handled properly. Given the present shortage of technicians, this is a good way to maximize the services and skills of existing specialists and to maintain quality control. Interestingly, other organizations like the USSR State Committee on Standards, the USSR Ministry of Chemical Industry, and the USSR Academy of Sciences have also begun to set up rental services involving very sophisticated equipment and precision instruments.[44]

Nonetheless, the inadequacy of supplies and the inefficiency of their administration remain constant complaints in the Soviet press. Here it is important to bear in mind that the supply function, like planning and financing, is fragmented among numerous organizations. There is no single master and allocation holder of material resources, though the State Committee for Material and Technical Supply (Gossnab) presides over one of the most extensive and powerful bureaucratic empires in the country. Still, more than 75 percent of the 7000 supply and marketing organizations belongs to various ministries and departments. "Subdividing supply functions," an article in Pravda notes, "has the undesired consequence that each branch of the economy strives to supply 'its own' enterprises first, frequently to the detriment of the state as a whole."[45] The cumbersome multi-level and multi-agency distribution system gives rise to poor coordination in planning, complicates work, and impedes the solution of even routine matters. Describing the defects of the system, the head manager of supplies for the Moscow region observed recently:

> The organizational structure of the USSR Gossnab and its agencies does not yet fully meet the demands of the national economy in as much as the share of material resources sold through this system is low, not over 50 percent.
>
> The nationwide system has still not become the basic, prevailing system of supply either at the center or in local areas. As a result, production associations, enterprises, construction and research organizations are compelled to use numerous additional channels to find and acquire the materials and equipment they need to fulfill their plans and meet their commitments.
>
> At present there are no firmly established procedures for planning and distributing the goods on the itemized lists stipulated by the USSR Gosplan and by the state economic plan. Naturally, this makes for considerable duplication in the work of the USSR Gosplan and Gossnab.[46]

Largely because of the difficulties in obtaining materials and equipment through Gossnab, R&D facilities and production units continue to bypass the whole material supplies system and try to satisfy their needs illegally and by direct acquisition from producing organizations.

THE SELECTION OF RESEARCH TOPICS AND TASKS

Program and project selection in Soviet R&D facilities reflects the combined impact of possibilities and objectives. Important factors influencing technical possibilities are current Soviet state-of-the-art; the state-of-the-art abroad and potential for foreign technology acquisition; and the quality and quantity of material, labor, and capital inputs that can be directed to technology generation and acquisition. Important factors influencing objectives are the level of the decision maker, his independent or derived aspirations, and the urgency of the technical problem at hand in comparison to other claimants on resources. Influencing both possibilities and objectives is the productivity of investment in particular programs and projects, or in other words, the value of the results which may be expected from a given amount of inputs. While the selection procedures and criteria clearly differ depending upon the agency and type of R&D, and though our knowledge of the details of Soviet decision making is still limited at all levels, the following description supplies the important principles and general procedures.

In all organizations and at all levels of the hierarchies the selection generally proceeds in three stages: (1) an evaluation of where the organization or entity (the nation as a whole, republic, or branch of the economy) is at a particular time; (2) an assessment of where the organization or entity is likely to be under the assumptions of combining possibilities with several variants of objectives; and (3) a selection of alternatives. The chief concern in the first stage is the set of indicators employed to evaluate status; in the second, techniques of forecasting; and in the third, the designation and hierarchy of plans, programs, and projects and the criteria of choice. The hierarchy of plans has already been described. Briefly, for definitional purposes, the program-oriented hierarchy is as follows. Important, complex S&T problems are broken down into targets, which in turn are subdivided into projects, operationally the basic unit of research. These may be further subdivided into tasks and even stages. Examples of each generally do not appear simultaneously in the same plan. Highly aggregated indicators tend to correspond to all-union and branch plans, while detailed indicators are found in plans of performer organizations.

Indicators of current technical or economic status are particularly important because they form the basis for all subsequent policy actions. Pertinent indicators, of course, reflect the R&D orientation of the particular decision-making unit, but they also show what the decision maker believes to be important. There is, then, a kind of circularity here: indicators which the performer knows to be evaluative influence his project selection and conduct.

In general, Soviet planning of science and technology has lacked until recently any formalized and uniform set of indicators to guide strategy and policy development. Individual ministries have followed different and often outdated regulations as well as specific orders and sometimes contradictory explanations of various agencies. Even the names and structure of R&D plans have varied from one branch to another. Among 20 ministries and departments in the Ukraine in 1973, for example, only three used the same indicators in the R&D divisions of their plans.[47] Also absent have been any guidelines for effectively linking the planning of R&D to the planning of industrial production.

Significantly, new planning instructions issued by Gosplan in 1974 seek to provide some systematic criteria for scientific choice. The instructions stipulate that the planning of S&T is an integral part of the planning of scientific and technical progress. Thus, the formulation of five-year and annual plans is to be oriented to accelerating the rates of scientific and technical advance and to raising the efficiency of production along the following broad lines:

1. The creation and introduction of fundamentally new tools, materials, and technological processes which surpass the best domestic and world standards
2. The comprehensive improvement of product quality in all sectors of the national economy
3. A rapid rise in the technical level of the stock of technological equipment and a faster pace of replacement and modernization of obsolete machines and units
4. A reduction in the amount of materials consumed in production by improving the product mix and the design of machinery, by using advanced technology, and by utilizing more fully raw and other materials
5. A rise in the level of electrification of production and in the efficiency of energy use
6. The creation of machine systems for complete mechanization and automation of the most important production processes in industry, construction, agriculture, and transportation
7. The renovation of existing and introduction of progressive standards and specifications for achieving a high technological level and quality of output
8. The broad introduction of modern methods of planning, organizing, and managing production, including the use of up-to-date business machines and computer technology.[48]

These broad directions, expressed in terms of appropriate volumes, rates, and proportions, have subsequently been referred to by Soviet science policy officials as "basic indicators" for measuring scientific and technical progress.[49]

In fact, the 1974 planning instructions included, for the first time, a list of "basic technical and economic indicators" for industrial production, which are directly related to the broad evaluative considerations noted above. Constituting a new subdivision of the plan for the development of science and technology, these technical standards are designed to serve several purposes. First, they provide criteria for determining the usefulness and desirability of proposed research, development, and innovation measures, and in particular for calculating the return on investment. Second, they induce enterprises to enhance technological performance, raise economic efficiency, and improve product quality. Third, they aim at enforcing the utilization of R&D results in production.[50]

In effect, these technical standards are to serve as the basic indicators for evaluating status and for determining technological advance throughout the planing hierarchy. The indicators are couched in general terms for application to the economy as a whole and to the republics, in intermediate terms for the various branches of the economy, and in highly specific terms for separate production units. The general indicators include, for example, the following:

1. The proportion of products matching or exceeding the best world standards
2. The volume of sales of such products
3. Changes in proportion and volume of substandard and obsolete products
4. The proportion of obsolete products withdrawn from manufacture to total products
5. The amount of production assimilated for the first time or assimilated in less than 3 years time
6. The degree of mechanization and automation of labor

7. Relative reductions in the labor force due to the rising technical level of production

8. Increases in labor productivity

9. Economies in the use of materials

10. Reducations in cost.

Indicators for each branch or enterprise specify the production standards required to meet the general indicators, such as, the average content of nutrients in chemical fertilizers, the drilling speed of oil and gas drilling equipment, and the proportion of total steel output per plant produced by the continuous smelting method.[51] The orientation of these indicators is clearly economic and demonstrates that pressure on the scientific community is strong and growing to induce all researchers, designers, and engineers to serve the needs of the economy.

It is of course difficult to conceive of a set of concrete indicators which might represent the level of achievement in a particular scientific discipline, especially in fundamental research. This is also attributable to the fact that no single organizational unit is held responsible for advance in a specific field, though leading Academy of Sciences departments, councils, and facilities would come closer to assuming this role than any comparable American facility. Accordingly, the state of advance in a scientific discipline is evaluated in informal discussion within the relevant scientific community and more formal deliberation in a scientific problem council of the Academy or of the GKNT responsible for the area. Soviet status relative to the rest of the world is also certainly an important consideration.

Prospective paths of scientific and technical advance are determined through forecasts, a procedure which really constitutes the first stage of planning. Much attention has been given in the USSR in recent years to S&T forecasting. Its development has been encouraged in large part to broaden the short time horizon and to alter the incremental style of Soviet decision making and thereby improve strategic planning in both science policy and economic policy.

S&T forecasts are projections of alternate trends in major areas of science and technology. The variants ultimately selected as a basis for planning reflect established priorities and preferred options, ideally arrived at by comparative evaluation of expediency, costs, and benefits. The approved forecasts are the foundation for so-called "basic directions in the development of science and technology during the five-year plan period." The incorporation in forecasts of the combined impact of possibilities and objectives is reflected in the fact that subsequent "basic directions" are designated as the framework for addressing the "basic S&T problems" listed in the five-year plan.

Forecasts may be short term (5-7 years), medium term (10-15 years), and long term (20 years and over) and impact on the respective plan periods accordingly. Short-term forecasts are used in machine building and metalworking to project new models of machinery and equipment. The longer term forecasts are used to project new types of products or engineering systems. They are commonly made for problems or areas of national importance, and sometimes for branches when the problem is clearly within the confines of a particular branch. Long-term forecats have been prepared, for example, for the fuel and energy balance up to the year 2000, for hydro-electric power, long-term chemicalization, and development of branches of heavy industry.[52]

Though more than 150 different forecasting methods have been developed, they fall generally into three major types: extrapolation, expert judgment, and modeling. Techniques of extrapolation are usually used in areas where changes are gradual and not disrupted by radically new discoveries. The future is projected largely on the basis of the continuation of present tendencies of development. In expert judgment, forecasting involves analysis of trends by groups of experts in particular fields and the weighing of opinions as to predominant probabilities in science and technology. The method of modeling consists of building information models, games models, mathematical models, and other systems of logic incorporating present and future technical and economic characteristics in particular fields of R&D.[53]

In general, methods of collective expertise and evaluation are most frequently used, particularly when broad or nebulous questions are under examination, such as prospective advance in an area of fundamental science. Modeling is least used. This is certainly in part due to the heavy demands placed on extensive and consistent data panels and on careful specification of parameters. Modeling is more amenable to such tasks as the projection of performance characteristics for certain categories of machinery and the development of branch-of-the-economy forecasts.[54]

On the procedural side, the forecasting of R&D of national or interbranch scope is directed and monitored by the "Big Four" planning agencies: the USSR Academy of Sciences, the GKNT, Gosplan, and Gosstroy (the USSR State Committee for Construction Affairs). The Academy and the GKNT, in particular, are the main agencies in this activity. Each maintains an elaborate structure of special problem councils and expert groups which separately and jointly conduct forecasting studies. S&T forecasting that is limited to an intrabranch focus is the province of relevant branch ministries, though subject to constraints imposed by central forecasts. Branch-wide forecasts selected by the ministries are also submitted to the "big four" agencies for review and approval.[55]

It needs to be noted, however, that the whole area of scientific forecasting and technology assessment continues to suffer from serious deficiencies. Long-range planning and forecasting are still relatively undeveloped on the branch level. Some branches, Nolting points out, do not even bother to draw up forecasts or perspective plans of intrabranch R&D. Forecasting in these ministries is confined to that portion of R&D conducted in connection with major interbranch S&T programs.[56] Serious complaints are registered regarding the quality of forecasts. The latter frequently do not take into account economic return, social consequences, the dynamics of prices, etc.[57] The real problem is that no universally acceptable methods have been found for evaluating these factors, nor is there any agreement on how they interface. Because of these general evaluative deficiencies, forecasting continues to have so-called "black spots" that reduce its value as an instrument of Soviet planning and analytical tool for deciding problems of choice. Nonetheless, with evaluations of current status and forecasts in hand, planners are prepared to select programs and projects.

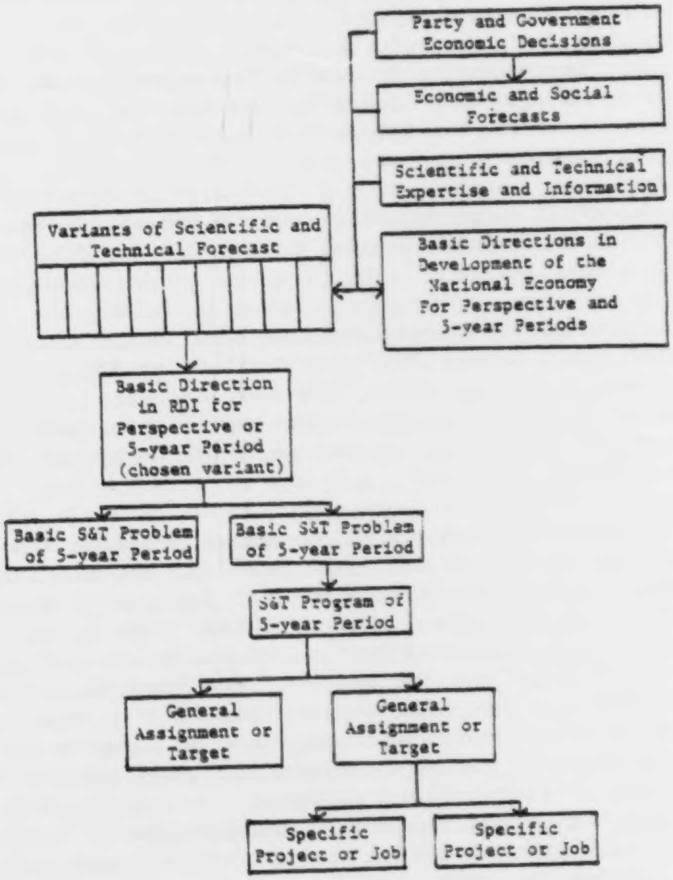
The selection of programs is an iterative process among experts and councils in a position to know the constraints placed on R&D by the availability of intellectual, human, and material resources, on the one hand, and the economic and political authorities who provide the objectives and orientation for science on the other. The selection of programs and projects and their subsequent disaggregation generally follow administrative lines corresponding to the infrastructure depicted in chapter 9. In important instances, however, problems are of interbranch significance, and R&D conducted on the problem requires coordination between Academy, university, and/or industrial facilities of several ministries. Similar, multi-facility programs are developed within ministries. The delegation and management of programs and projects, both administratively and functionally oriented, is discussed in greater detail later in this chapter. For now, attention is given only to the selection of original projects at various levels and particularly the criteria of selection.

National and branch long-range plans for S&T are essentially a bridge between forecasts and the five-year plan. The long-range plan is "apparently a tentative selection of the variants of basic directions yielded by the forecasts and sets forth in broad terms the new technology to be developed."[58] Five-year and annual plans are the operational periods for program selection and control, and the basic S&T problems that are included in the national economic plan form the orientation for much of the R&D performed in the Soviet Union, both because of their magnitude and the high priority attached to their solution. In the Eighth (1966-1970) and Ninth (1971-1975) Five-Year Plans the basic problems reportedly consumed about 40 percent of the allocations to science, while in the Tenth Plan (1976-1980) they garnered about 25 percent of the official science budget. The number of problems has also been reduced from nearly 250 to around 200. The links between S&T forecasts, basic directions, and basic problems as well as the latter's subsequent breakdown into programs and projects are depicted in Figure 10-3.

The list of basic S&T problems is prepared by the State Committee for Science and Technology in collaboration with Gosplan and the Academy of Sciences. Apparently only about 10 percent of the problems--the most important--actually go to the Council of Ministers (and most likely the Politburo) for approval at the highest level, but this portion probably absorbs more than half of all expenditures. The rest are more likely then approved on the spot by the "Big Four" central planning agencies.[59] The largest of the work programs associated with these problems undergo expert evaluation at the State Expert Commission of the USSR Gosplan. For individual programs, the GKNT organizes the expert judgment. The basic criteria for the selection of these problems of national priority are their interbranch importance, their social significance, and the technical-economic benefit to be derived from their solution. The list of basic problems reportedly contains no military projects.[60]

A basic S&T problem is defined as a complex of interrelated tasks, the fulfillment of which plays an important role in accelerating technological modernization of the national economy as a whole. The "solution" of a problem takes generally one of the fol-

FIGURE 9-3 COMPONENTS OF THE SYSTEM OF RESEARCH, DEVELOPMENT, AND INNOVATION PLANNING IN THE USSR


Party and Government Economic Decisions
Economic and Social Forecasts
Scientific and Technical Expertise and Information
Variants of Scientific and Technical Forecast
Basic Directions in Development of the National Economy For Perspective and 5-year Periods
Basic Direction in RDI for Perspective or 5-year Period (chosen variant)
Basic S&T Problem of 5-year Period
Basic S&T Problem of 5-year Period
S&T Program of 5-year Period
General Assignment or Target
General Assignment or Target
Specific Project or Job
Specific Project or Job

Source: Louvan E. Nolting, The Planning of Research, Development, and Innovation in the U.S.S.R., p. 20.

lowing forms:

1. Development and assimilation of new systems of machines, new equipment for mechanization and automation, and new materials and products
2. Development and assimilation of improved technological processes and methods of reducing environmental pollution
3. Improvements in production organization and management, including the introduction of automated control and management information systems
4. Work on problems in the fields of construction, architecture, agriculture, and public health.

To solve the 200 basic S&T problems in the current Tenth Plan, nearly 1900 new kinds of machines, instruments, and products, 900 new economical materials, more than 1000 new technological processes, and about 700 automated control systems are slated for development.[61]

In general, fundamental research problems are not included among the basic S&T problems but are listed among the problems in the natural and social sciences, which are also funded from the State Budget. For example, only six percent of the basic problems in the Eighth Plan incorporated the fundamental research stage, but none was limited to it. More than half of the problems were confined to areas of applied research and/or development. Only about 40 percent of the problems extended through the stage of innovation and production assimilation.[62] In accord with the increasing emphasis in science policy on the need to utilize R&D results in the economy, the list of 200 basic problems in the Tenth Plan contains a greater proportion of innovation-directed projects. More than half of the new hardware, technology, and materials in development are planned to be carried through to the phase of trial lot production or to the successful operation of production processes.[63]

To illustrate the nature and variety of basic S&T problems, let us offer the following examples from the Tenth Plan. There are programs devoted to the development and expanded use of numerically-controlled machine tools and the development of modern equipment for mechanizing and automating local materials handling and warehouse operations as well as timber cutting. Other programs focus on raising the unit capacity of machines and equipment, especially for the chemical, power, and ferrous metallurgical industries. These include building large ammonia producing plants, and turbines and generators with a capacity of 500, 800, and 1000-1200 megawatts; developing ultra-long 1500 kV DC and 1150 kV AC transmission lines and nuclear power plants equipped with 1500 megawatt reactors; and designing special excavating machines with 40, 65, and 180 cubic meter bucket draglines for coal mining.

On another level are basic problems in the development of furnaceless metallurgy, spindleless spinning, and shuttleless weaving. New methods of producing metal and high-grade steels, including oxygen converters and electric smelting, are the subjects of other programs. At the Oskol Electrometallurgical Combine technology will be introduced for the production of steel by direct reduction of iron ore without blast furnace processing. Still other programs concentrate on the production of more efficient materials, such as synthetic resins and plastics. Developments in laser technology and in industrial robots also figure among the basic S&T problems.

Finally, problems in applied research--rather than development or innovation--include programs on the use of scientific principles of superconductivity and magneto-hydrodynamics, space and oceans research, molecular biology, and seismology. A basic S&T problem in the field of public health concerns the development of methods and means for the prevention, diagnosis, and treatment of cardiovascular disorders. Other programs deal with ways to protect the soil against erosion as well as research on plant nutrition and ways of raising soil fertility.[64]

The procedure for project selection at lower levels of the hierarchy is similar, although correspondingly shorter and simpler with fewer organizations involved. In Academy and university facilities, "initiative" fundamental research not associated with problems of superior bodies or contractual obligations materially reflects the professional interests of the individual or research collectives. In industry, ministries define problems of branch importance in the same way that all-union R&D problems are defined. The ministry scientific-technical council is the chief consultative body. Large production associations and other establishments may engage in a similar procedure. In general, while personnel in industrial institutes, design bureaus, and production establishments may have some latitude to pursue their professional interests, the heavily applied nature of the work at these facilities severely limits the scope of R&D.

Indeed, the selection process itself is influenced by the character of the R&D in question. While the consumer of the results frequently influences project selection in industrial R&D, the resource base--the qualifications, creative potential, and experience--of the fundamental research organization also tends to limit the scope of its work. In planning fundamental research, Larichev notes that "the resources of the executors predetermine to a considerable degree the goals that are achieved." On the other hand, for predominantly development-oriented projects "the composition of the performers has comparatively small influence on the goals that are achieved; the same R&D can be assigned to different groups of performers." Applied R&D occupies an intermediate position in this regard.[65] Academician Kapitsa also observes that with fundamental research planning "the choice of talented individuals should have priority, even over the choice of subjects." As he points out, "A lame man cannot be taught to run however much money is spent on him."[66]

Precise figures are not available on the proportions of R&D directly planned by central authorities, the branch ministries, and local R&D performers. Although the 200 basic S&T problems account for only about 25 percent of total official R&D, central planning is not limited to these programs and may approach 40 to 50 percent, in Nolting's opinion. Ministerially planned R&D activities constitute probably about 30 percent of the total effort while lower level performers account for the remainder.[67]

Throughout the discussion of selection, we have referred to the pertinent criteria. In general, at all levels and in all organizations criteria may be grouped in three categories--economic, technical, and social--with emphasis on the first. The criteria themselves also are similar throughout the economy, with allowance for the pertinent arena of the decision maker. Both the problems and the answers should generally be formulated in a language appropriate for the given planning environment. That is, scientific evaluation, Larichev explains, "in spirit should be a concrete response to problems of the planning organization." "Logical models of information conversion which use verbal definitions of qualities are more practical than mathematical ones," he adds.[68] In general, strong preference exists for relatively simple evaluative methods and indicators rather than for highly sophisticated analytical techniques and complex quantitative formulas. For the most part, R&D questions are seen by Larichev and other Soviet science analysts to fall into the class of "weakly structured decision problems," for which modern systems analytic techniques, including cost/effectiveness methods, are not very useful. Only in the more deterministic world of production-oriented development projects are these conceptual aids deemed to be of value in planning and deciding problems of choice and uncertainty.[69] Also as a general rule, Kapitsa notes that the figures to be watched in project planning are not the absolute ones but the relative indices--the percentages of the total used for salaries, for administration, for scientific equipment, etc.[70]

Until the late 1960s, economic criteria did not figure prominently in Soviet R&D decision making. Scientists and engineers were generally not sensitive to parameters of "cost" and to constraints on resources. Their dominant attitude, as expressed in the Academy's main journal, was that "there is no unequivocal criterion for the resources that should be allocated to science. All of us must try to obtain the greatest amount of resources possible."[71] Once when commenting upon the difficulties the leadership faced in drawing up the first list of basic S&T problems, Academician Kirillin, Chairman of the GKNT, observed that scientists did not always help policymakers resolve the problems of choice. They willingly gave positive endorsements and sometimes were indecisive about a particular problem. But almost never did they render negative opinions.[72]

Similarly, the economic benefit or return of proposed R&D was not always considered, much less calculated, in the selection process. In 1968, for example, the branch plan for the development of new technology prepared by the Ministry of Instrument Making, Automation Equipment, and Control Systems included estimates of the economic return for only six percent of its applied research work, for about 30 percent of the undertakings devoted to the creation of management information systems, and for about 60 percent of the projects dealing with the development of new instruments and means of automation.[73] The absence of calculations of economic return is explained in large part by the fact that they were not obligatory at this time. "Without estimates of economic return," E. V. Kosov notes, "It is impossible to evaluate and compare the activity of organizations working in the field of science and technology."[74]

Suffice it to say that since the late 1960s Kremlin authorities have mandated that all R&D projects in the plan must be supported by calculations of economic return redounding to the users of the new technology and to the economy as a whole. The main aim of this requirement is to weed out nonpaying, impractical R&D, to promote technological innovation, and to raise the general cost-effectiveness consciousness of the R&D sector. For basic S&T problems of national priority, the prescribed indicators of economic effectiveness include specific capital investments, labor costs, expenditures on materials, electric power per unit of increase in production capacity, and general expenditures in terms of cost. For each problem there is also compiled a technical level chart which compares the projected new technology with the best domestic and foreign technology, indicates the branches of the economy in which the new technology is to be applied, and gives rough projections of the demand and export potential for the new or improved technology.[75] The economic orientation of the criteria and their similarity to the indicators of development described earlier are apparent.

Nonetheless, the requirement to include calculations of economic return in R&D planning is not universally observed and enforced. Basic science appears generally to be excluded from this policy and from the subject matter of the "economics of research," a special field of study that has emerged in the USSR since the mid-1960s. As one of its leading experts observes,

> It is not possible to reduce the labor embodied in Mendeleyev's discovery of the periodic table to the cost of the cards on which the atomic weights of chemical elements are entered and to the cost of the sheets of paper on which Mendeleyev recorded his idea of the periodic law.[76]

More broadly, too, cost/effectiveness estimates tend to be neglected or are elaborated pro forma simply to justify decisions already made. The crux of the matter is that no uniform set of procedures has been established for defining and calculating economic return applicable to individual branches and enterprises. In general, L. Gliazer notes, "Almost all economic calculations that are presently made in science have a low degree of reliability. Here broad use is made of various kinds of analytical techniques that impart the appearance of objectivity to all manner of subjective constructions."[77] S. M. Yampolskiy also concludes that the calculation of economic return has been made mandatory, in effect, only for projects of major importance approved by the USSR Council of Ministers or for special bonus projects in which an enterprise assimilates a technology new to the USSR.[78]

Even for the highest priority basic S&T problems, however, economic analysis has limitations and deficiencies. Among the current 200 basic problems economic return was not determined in a number of cases, nor were the technical level charts always complete and accurate. In some instances, information was lacking on important indicators. Analogies were sometimes used and not the latest achievements in comparing technological merit. As a GKNT official notes, "All this prevented the conduct of careful analysis and expert review for all the problems. It is necessary to give more attention to analysis and evaluation of new technology, to make more precise the information on the technical level charts."[79]

Studies by Soviet science policy specialists in the early 1970s exposed a number of analytical and methodological deficiencies in the handling of this special class of decision problems. Commenting on the experience of cost overruns--sometimes quite staggering--among the 246 basic S&T problems during the Eighth Five Year Plan, Kosov and Popov concluded that "cost" was not, in fact, substantiated in the system of coordination plans for these problems. No reliable or universal methodology was used in calculating the cost of either individual projects or programs as a whole. Nor was there any consistent effort to relate cost to economic return. Economic return was not an important or obligatory object of planning. There was also some duplication among the problems so that parallel programs existed, for example, on developing new kinds of paper, new types of irrigation systems for agriculture, and data processing systems for handling S&T information.[80] Other specialists, including O. I. Volkov, Boris Zaitsev, and Boris Lapin, also conclude that the coordination plans for 1966-1970 were deficient in "economic effectiveness."[81] For the most part, the methods of planning basic problems did not change until the Tenth Plan, when central authorities tightened up on procedures and laid down the "basic technical-economic indicators" to guide the selection process.

All the same, despite improvements in calculating effectiveness, economic return on R&D is not an absolute criterion for selection of basic problems. There are other factors, such as national prestige, defense, social and even technological goals, that may override considerations of economic benefit and cost/effectiveness ratio. V. N. Arkhangelskiy, a major authority on the planning and financing of R&D, labels this the "criterion of necessity." In cases where this criterion applies, he writes, only the cost and not the economic return need be estimated.[82] Though he gives no specific examples of basic S&T problems that fit this category, we can surmise that "necessity" may have determined the choice of some of the research-oriented problems in the areas of space, oceanography, public health, and atomic energy. Examples of past technology-oriented basic problems that may have been perceived in these terms were the development of the Soviet supersonic transport plane, the TU-144, and the new series of _Arktik_ class atomic ice breakers.

Even more difficult to quantify than economic criteria are the two others, technical and particularly social criteria. But these exert significant influence on project selection. The project to mechanize production operations at the large ZIL truck plant is a case in point. As a Soviet case study of the decision-making process that underlay this modernization program notes:

> The program of reconstruction had great economic, technical, and social significance.
>
> The economic significance of the program consisted in that it was viewed as the creation of significant economic return: the growth of labor productivity, increase of profitability of production, and guaranteeing stability of quality production.

> The technical significance of the program consisted in the changeover to a new base model of truck, the ZIL-130, instead of the ZIL-150, in simultaneously increasing production from 100 to 200 thousand trucks per year, and in the introduction of basically new technical solutions in the areas of welding, forging, assembly, transport, and other technological processes.
>
> The social significance of the program consisted in that it was viewed as a first order mechanization and automation of labor intensive and heavy work, as well as of unattractive or harmful operations. Significantly improved were the working conditions. Social significance of the program also consisted in the fact that it can be seen as the accomplishment of large social measures in the localities of the main plant and its branch facility: large residential and cultural construction, including the building of health and sports facilities, nursery schools and pioneer camps, etc.[83]

Though automation brings obvious economic benefits in higher productivity, the social consequences associated with alleviating or eliminating heavy physical labor appear to be further considerations behind at least two of the current basic S&T problems. One of these deals with the development of modern machinery for handling materials and mechanizing warehouse operations; the other focuses on equipment to mechanize the process of timber cutting. The social significance of these programs lies in the fact that one-third of all Soviet industrial workers are still engaged in manual labor and 16 percent do heavy physical labor.[84]

In another example, ecological factors are said to have been of importance in the development of the 250,000 kilowatt thermal-electric turbine, one of the early "basic S&T problems" selected by the regime:

> Combined heat and power supply also has great social significance, since it facilitates an increase in the purity of the atmosphere, a reduction in

> thermal pollution of reservoirs and an improvement in the comfort of industrial buildings.
>
> Combined heat and power supply eliminates the requirement for individual, small fuel-consuming heaters. The use of powerful sources for the combined generation of heat and electricity makes it possible more effectively to organize purification of the smokestack gases of steam generators of fly-ash particles, which, for the small or even large urban boilers, is difficult to accomplish in terms of both the volume of work and capital investments required.
>
> As a result, the number of harmful discharges of ash, sulfur oxides and nitrous oxides into the atmosphere is sharply reduced.[85]

We noted earlier that the list of 200 priority S&T problems in the Tenth Five Year Plan includes R&D programs in environmental protection. While "environmental impact statements" have not yet become mandatory in Soviet R&D planning, the importance of ecological factors is definitely rising. Academician N. P. Fedorenko writes, "Most economists now share the opinion that purely economic criteria are becoming increasingly inadequate as indicators of the optimality of economic growth and should be supplemented with social and ecological indicators."[86]

In general, though, there is still much room for improvement in the selection of R&D programs. The social impact of new technology has only recently become an object of planning, and the methods of evaluating "social effectiveness" are still undeveloped. The new technical-economic indicators established by Gosplan in 1974 have not yet become a firm basis for standardizing the calculation of economic return and technological level of prospective R&D. Their application is still experimental, and opposition runs strong in the ministries against centralization of technical decision making. Given these circumstances, Louvan Nolting concludes, "As in other countries, rough rule-of-thumb balancing of economic and societal interests will probably continue to be the principal method of regulating technical progress in the Soviet Union."[87]

As regards the most important S&T problems in particular, deficiencies in decision making and administration persist despite recent efforts to wrap these processes in more modern clothes. To be sure, some progress has been made in conceptualization of what should be the parameters of a basic S&T problem. The initial list, hastily formulated in 1965, displayed a 5000 percent difference in the cost range between the least and the most expensive problems, suggesting substantial weaknesses in defining the criteria of choice for including a particular topic on the priority list.[88] Nonetheless, there are still no uniform criteria or adequate procedures for screening this class of problem, and it remains a general catchall category. Not all really important problems are put on the list, and some topics are included at the suggestion and under pressure of ministries and departments although they are, in fact, not of major importance. Not all the basic problems are interbranch or of national significance.[89]

Finally, special mention must be made of the role of "inertia" in the selection and retention of Soviet R&D programs. Investments already made and projects in progress predetermine to a large extent the content of future plans. They constrain the options and possibilities of planners to undertake new starts. The task of preparing the five-year plan has been likened by one Soviet observer to the problem of trying to buy new furniture for an apartment when one-third of the pieces are already there and another third is on order.[90] Indeed, almost two-thirds of the current 200 top priority S&T programs have been carried over from the Ninth Plan.[91] The basic problems in the Ninth Plan, in turn, were mostly continuations of projects that were begun in the Eighth Plan when the list of basic S&T problems was first established.

This continuity in Soviet planning is characteristic more generally of a fundamentally conservative approach to technological and economic development. The tendency to plan "from the achieved level," which holds sway throughout the system, reflects what has been called an "add on" philosophy of design and mode of advance. Strong preference and aptitude exist for improving and scaling up existing processes rather than for developing basically new processes and products. This is seen in the scaling up of blast furnaces in the iron and steel industry and of gas and electric turbines and generators in the power industry. In aviation, the development of a new aircraft tends to incorporate existing technology rather than depend upon successful new advances in airframe, engine, and avionics. Similarly, the Soviet space program has relied heavily for a long time on the Vostok launch vehicle, and spacecraft have been developed not by designing a new craft for each mission but by building on to a standard craft. By contrast, there have been great technological differences in the American program among the Atlas, Thor, Titan, and Saturn rockets, as well as among the Mercury, Gemini, and Apollo spacecraft.[92]

In addition, the rate of diffusion of new technology in the Soviet Union is comparatively slower than that in most industrial capitalist countries. During the past 20 years, some major traditional industries have continued to expand rapidly while in other countries their rate of growth has slowed appreciably. In the steel industry, for example, production by traditional methods continued to grow even after the introduction of oxygen smelting and continuous casting, while in the West the new processes have tended to drive out the old. The diffusion of synthetic fibers has also been distinctly slower. As a general rule, the rate of capital retirement is much lower in Soviet industry, and new products and processes take longer to capture a significant share of total output.[93]

While these features of Soviet development reflect in part a more conservative pattern and structure of industrial production, they are also due, it seems, to insufficient attention to alternative or more recent processes at the R&D planning stage. This is the conclusion of a group of Western scholars at the University of Birmingham. In their recent study of the technological level of industry in the USSR, they note that Soviet authorities almost ignored alternatives to their own SKB process for the manufacture of synthetic rubber. New processes for making alloy and quality steel other than electric slag remelting also received inadequate attention.[94] As we have seen, the basic Soviet organizational approach has been to concentrate responsibility for industrial R&D in large branch institutes and design bureaus under ministerial control. Complaints are frequently voiced in the Soviet press that these units display monopolistic attitudes and an aversion to experimentation. Interestingly, the new basic technical-economic indicators, laid down in 1974 to guide R&D decision making, have also been criticized on the grounds that they essentially preserve existing production methods with only marginal improvements and tend to preclude radical technological change.[95] Overall, as the Birmingham study concludes, the Soviet pattern of innovation and philosophy of design have been responsible for the incremental and conservative mode of technological advance in the USSR, as well as for the loss of tempo and of technological lead, at least in some areas, in relation to the United States over the past two decades.[96]

THE DISAGGREGATION AND ASSIGNMENT OF RESEARCH TASKS

A large and frequently major share of the content of the research plan of a management organ or research establishment is composed of assignments specified by a superior agency and/or contractual obligations resulting from negotiations with organizations sponsoring R&D. Earlier in this chapter, it was noted that Soviet research assignments are delegated both on an administrative basis, with a hierarchy of tasks corresponding to organizational affiliation, and on a program basis, where problems and programs cross formal departmental boundaries. In this part, we first briefly describe the traditional process of vertical disaggregation of plan tasks, and then discuss horizontal relationships among performing and sponsoring organizations on the same level. We then focus on interbranch S&T problems.

Vertical Relationships

Disaggregation of plan assignments along vertical administrative lines still constitutes the basic framework for planning research, development, and the implementation of results. In large part, this is because most such assignments fall naturally within the purview of a traditional organizational entity, such as a ministry, which generally is constituted on thematic grounds. In addition, other chapters of the overall plans, including those concerned with production, supply, and finance, are formed even more completely by vertical disaggregation of assignments. Because R&D-related targets must be well coordinated with other targets, there is a strong case for similarly managing plan formulation. This rationale suggests the most telling reason for the maintenance of the vertical relationship: the process is already so complex and demands the integration of so many participants that to require the performer to synthesize and establish priorities for directives coming from several sources would bring the system to a grinding halt. Accordingly, even priority directives originating from interbranch programs must be incorporated in the traditional vertical planning process at the level of the intermediate management organ, such as the ministry.

The R&D planning process follows, on the whole, the main lines of the overall planning process. The formal procedure occurs in four stages: (1) transmission of directives to lower organs; (2) presentation of draft plans to higher authorities; (3) approval of the plan and its transmission; and (4) adjustments to the plan. These distinctions or stages represent only a first approximation, however. As Zaleski explains, "In fact, planning done by higher and lower organs is generally simultaneous, and the directives and approvals are often replaced by bargaining and mutual agreement."[97]

Chronologically, for the annual plan, general directives for the plan year should be formulated early in the preceding year by the Politburo and Council of Ministers. The Academy of Sciences, Gosplan, and the GKNT, representing their respective areas of R&D, coordinate and establish the basic objectives, rendering them more detailed and comprehensive. The GKNT, in particular, has overall responsibility for plan formulation on the functionally oriented program plans. "Control figures," or preliminary plan assignments, are transmitted down the respective hierarchies--Academy, ministry, republic--to the performing organizations. This stage should be completed by the middle of the year.

Establishments prepare draft plans which are routed up through the hierarchy, aggregated at each stage. They are considered and reconciled (with bargaining) by the triad of central management organs noted above. This stage should be completed by the end of September. Plans are then approved by the Council of Ministers and the Politburo, approved by the Supreme Soviet, and transmitted down the administrative ladder with formal and official plan assignments specified at each level. Preparation of five-year plans proceeds in a similar fashion with, of course, a different time frame.

Integration of the various sets of plan targets contained in the separate plan chapters is highly important and sometimes essential. At the least, for example, supply and production targets must be largely consistent, but the same is true for R&D and especially innovation targets. The latter assignments generally disrupt normal establishment operations and, if not accounted for in the plan, may thereafter threaten fulfillment of primary production tasks. On the positive side, primary production assignments can function as a strong stimulus to innovation if they are predicated upon successful innovation, such as the assimilation of a new process which economizes on inputs. In other words, meeting production targets may require that an innovation be completed. Accordingly, it is expected--though not always realized--that targets for R&D and especially innovation be formulated in advance of production targets.

Specific procedures in different administrative hierarchies vary as a function of the orientation of the hierarchy and the nature of R&D activity. In the Academy of Sciences, for example, R&D is the central activity, and the uncertainty of fundamental research renders it difficult to formulate "hard" target indicators and thereby places a premium on expert consultation and evaluation. Also because of the long-term nature of basic research, five-year plan assignments for fundamental research in the natural and social sciences, though they do specify projected results, performers, and schedules, are not formally elaborated into annual components; and they are treated more as recommendations than as requirements.[98] In general, basic research is planned as part of the formulation of long-term trends and forecasts. The Academy of Sciences has also been delegated responsibility for its own planning. Not surprisingly, this tends to be much less bureaucratically oriented than in the branch ministries. There is broad participation through an elaborate network of consultative and evaluative councils throughout the Academy structure.

Indeed, the contrast in the roles of the various scientific problem councils of the Academy and the official planning agencies is worthy of emphasis and elaboration. The councils are consultative bodies composed of leading experts in different fields of science and technology. They have no formal administrative authority and their roles are somewhat ill-defined, yet they frequently exert considerable influence over the course of research. They not only examine general themes of research, but they may also recommend divisions of assignments among institutes and departments of institutions. The councils carefully review draft plans and suggest changes. Conversely, the role of planning agencies, certainly Gosplan and probably to some extent the GKNT, is limited. While their formal powers are well-defined, they normally function in the more deterministic world of production and innovation. The relative autonomy enjoyed by the Academy system clearly is attributable more to the nature of fundamental research than to any conscious decision on the part of the regime. Indeed, any degree of autonomy is likely to be granted grudgingly.

This leaves open the question of how the leadership influences the course of Academy and university fundamental research. While certainly not well defined, the process of issuing "basic directions" for science and technology appears to be significant. Unlike plan targets, basic directions do not have the force of law. In an important way, however, they partly substitute for plan targets in areas where (1) superior agencies are not qualified to fix detailed plan assignments, or (2) superior agencies are not administratively capable of determining appropriate targets.[99] The former concerns situations where the performers themselves are uniquely capable of determining the specific course of their work (e.g., Academy departments). Political authorities, for example, would not regularly presume to judge the merits of this or that research project in theoretical physics, but, by specifying the broad objectives to which a department's research program should contribute, the leadership guides the selection of assignments.

The second condition is more interesting because it is pervasive in science and the economy. Optimally, decision making at all levels should be channeled by a combination of specific orders, incentives, and penalties to assure that all activities contribute to the accomplishment of goals set by the central leaders. In fact, decision makers frequently have substantial autonomy, either because activities under their jurisdiction have not been adequately encompassed by the instructions of superiors or because elements of these instructions may conflict. In such instances, the basic directions provide a set of highly visible priorities to which decision makers can flexibly relate in deciding problems of choice. Basic directions facilitate the practice described by American observers as "decentralizing through priorities." In an important way, then, they form "a parallel mechanism to the plan, ideally correcting for the plan's limitations and contradictions."[100] Finally, the significance of the "basic directions" has been attested to in a message by General Secretary Brezhnev to the Academy of Sciences on its 250th Birthday:

> Scientists and specialists in the various branches of the natural sciences, technology, and the social sciences have given and are continuing to give the Party enormous help in accomplishing all these tasks and in working out plans and implementing them. For this, the Party gives them all heartfelt thanks.
>
> However, comrades, in the future you will have to work even harder, more persistently and more effectively. We have no intention of dictating to you the details of research topics--that is a matter for the scientists themselves. But the basic directions of the development of science, the main tasks that life poses, will be determined jointly.[101]

In the industrial ministry hierarchy, research, development, and innovation objectives must be incorporated with other economic goals. The character of R&D at this stage, especially the increased predictability of results, eases the task somewhat. The disaggregation is usually straight-forward, although difficult to realize in practice. Targets of all-union importance, by way of the GKNT, are included in plans of ministries along with tasks of branch significance initiated at that level. As a rule, the technical administration of the ministry is charged with formulating branch targets, a process which in principle is conducted in close coordination with the economic-planning, supply, finance, and other administrations. Targets are subsequently transmitted to the institute, design bureau, association, and enterprise, and form the core of plans at that level. There, too, responsibility is similarly distributed. R&D and innovation plans are the province of technical departments which similarly cooperate and coordinate with other functional departments.

We know relatively little about the criteria for selection of a particular facility to conduct a given project. According to Soviet science policy experts, the main factors that govern the distribution of assignments in the Academy, for example, are the general specialized profile of an institute, the qualifications of scientific personnel, and the potential of an organization "to deliver."[102] Other evidence suggests that the nature of the task and the responsible management organ virtually predetermine facility selection. The Soviets have long stressed extreme specialization by institutional performer to eliminate "wasteful" duplication of effort. Hence, the optimal facility may be apparent. If several facilities should be attractive candidates, another criterion takes over. The "autarchy" of Soviet bureaucracies has long been noted. If facility selection is not made at the highest levels, delegation of the task to an Academy department, industrial ministry, or the Ministry of Higher and Specialized Secondary Education probably settles the matter. Given the strong sense of "branch patriotism" and jealously guarded departmental domains, the advantage of an "outside" facility must be very great before a management organ will choose it over one of its own organizations. In some instances, tasks are assigned and conducted on the basis of "competition," and two or more facilities are enlisted to work on a particular problem. In general, competition is resorted to only when there are very great complexities and uncertainties surrounding a given problem. The military sector has been known to use this device, as has the aviation industry in the design of new aircraft.

In summary, the planning process is highly structured with only a little room for flexibility. Yet, it is apparent that the leadership has no intention of drastically weakening or confusing the somewhat ponderous vertical chain of command. The use of the GKNT and increased autonomy accorded to facility management do represent, however, efforts to enhance flexibility and responsiveness at, respectively, the highest and lowest levels. Recent Soviet developments in the application of integrated planning and control techniques at the branch level are discussed shortly in connection with multi-agency programs.

Horizontal Relationships

Horizontal relationships among facilities at comparable levels within and across the various bureaucratic subsystems, of course, are essential for the functioning of any economic system. At the very least, supplier-customer relations must be well elaborated, including those for which the product is R&D results. Traditionally in the Soviet system, however, the arrangement of such relations has not been handled directly by the facilities involved, at least not formally, but rather by officials in the facilities' parent management organs. For example, with transmission of technical documentation and other "disembodied" technology, Academy departments and ministry technical administrations would be expected at least to approve and possibly to plan the transfer. For a new project used as capital equipment by a second facility, the transfer would be more complex. The producing ministry's technical and economic-planning administrations would jointly plan the production. They in turn would coordinate with their ministry's Main Administration for Sales (Glavsbyt), which would arrange the transaction with the consumer ministry's Main Administration for Supply (Glavsnab). The latter, in turn, would represent and interact with the consumer establishment.

In practice, of course, the procedure has necessarily been more flexible, with substantial formal and informal interaction between producer and consumer organizations. Still, it generally does not approach the degree of freedom enjoyed by American businesses in extrafirm negotiations. All Soviet middle-level management agencies still retain these functional administrations with unchanged formal responsibilities. It may be expected that projects and transactions of an all-union and branch significance are carefully planned and negotiated in the traditional fashion.

Nonetheless, one of the important managerial innovations in recent years is the expansion of contract R&D. While generally incorporated in plans for formal approval, contract research may be arranged at the initiative of the performing establishments largely free of excessive restrictions or petty tutelage of superior organs. The primary motivation behind the change is the leadership's desire that independent research facilities better serve the needs of the economy. The motivation was imposed on many R&D facilities. In 1962, independent industrial research units began to be transferred to khozraschet operating principles, a transfer which, as previously noted, implies that they must support themselves on the basis of revenue earned from the sale of research. Of course, the state and ministry are still major purchasers, but the change means that budget grants are no longer readily awarded to account for excess capacity.

Several features of contract research merit attention. Though contract regulations usually contain elaborate provisions regarding the costing of work, there is room for maneuver. If during the course of the work unanticipated expenditures arise, supplementary arrangements may be negotiated to a total value of up to 50 percent more than the originally agreed sum. On the other hand, if an R&D organization manages to complete a contract for less than the fixed sum, it may retain the balance.[103] This prospect of acquiring extra discretionary funds, which can be used to buy equipment and thus broaden their own experimental facilities, acts as a strong incentive for research establishments, especially in the

Academy and the VUZy, to undertake contract research. Another attraction of contracts for the VUZy is that staff members working on contract R&D receive additional pay (up to half of their base salary). Those working on state budget-financed projects--no matter how important they may be--get no extra money.[104] These important incentives also increase the leverage of the consumer organization to obtain quality work on time and within cost.

Today, contractual research is well entrenched in Soviet industry, particularly within the confines of individual ministries. R&D facilities in various sectors of machine building are particularly known for contract research. This form of financing and distribution of assignments is also employed in interbranch industrial R&D projects. Contract research has also expanded recently between industry and both Academy and university facilities. While contractual R&D negotiated between performer establishments clearly must take second place to budget-financed tasks of all-union and branch importance, it does create flexibility in the system and promote linkage among the diverse participants in the research-to-production cycle.

At the same time, there are still serious deficiencies in the whole system of economic contracts that limit the effectiveness of this managerial mechanism of assigning and coordinating plan tasks. The crux of the matter is that contractual commitments are not really binding and cannot guarantee the accomplishment of fixed assignments. As a worker at the Academy's Institute of Organic Chemistry recently observed, "Experience shows that the partner from industry can at any time and for any reason terminate a contract without assuming any material or moral responsibility for this."[105] The monetary sanctions for failure to meet contractual obligations are minimal. They are sometimes even paid for out of state budget funds. More important, violations of contracts do not adversely affect the evaluation of the offending organization's economic performance, nor do they impact in any meaningful way upon the latter's incentive funds. In short, contractual conduct is not a primary performance indicator for Soviet institutions or a significant force in Soviet economic life. Furthermore, contractual relationships and commitments between performer and consumer establishments do not include supply organizations and hence do not influence the latter's behavior in meeting the needs of contracting parties.[106] The system of contracts as such does not and cannot insure the mutual responsibility for the fulfillment of assumed tasks. It is not an effective legal instrument for conducting business. Its basic deficiencies are a continual reminder that the Soviet system is fundamentally a system of administrative rules and plans, not a system of law, at least in the Western sense of the term.

Multiagency Programs

Earlier in this chapter we discussed the procedure and criteria for designating important S&T problems. By design, all elements of the problems are delineated with relatively little consideration of the organizational infrastructure supporting research and development. The leadership intends that the problems be defined on technical and economic grounds and not be artificially circumscribed by organizational considerations. Partly as a result, most problems are of interbranch importance, sometimes involving facilities from all of the R&D hierarchies. Hence, special plans or programs are developed to direct work on such problems.

In the Eighth (1966-1970) and Ninth (1971-1975) Five-Year Plans the main managerial device for integrating the whole complex of tasks and projects involved in solving a priority S&T problem was called a "coordination plan." In the Tenth Plan coordination plans have been replaced by "scientific and technical programs," which are generally more comprehensive and specify more clearly the introduction of results. There were approximately 240 coordination plans and are now about 200 programs, the reduction in number largely accounted for by the greater comprehensiveness of programs. Responsibility for a particular basic problem is assigned by the GKNT to the most appriate ministry or department, designated the "head ministry" or lead agency. As a rule, the latter is the main consumer of the results of the solution to the problem.

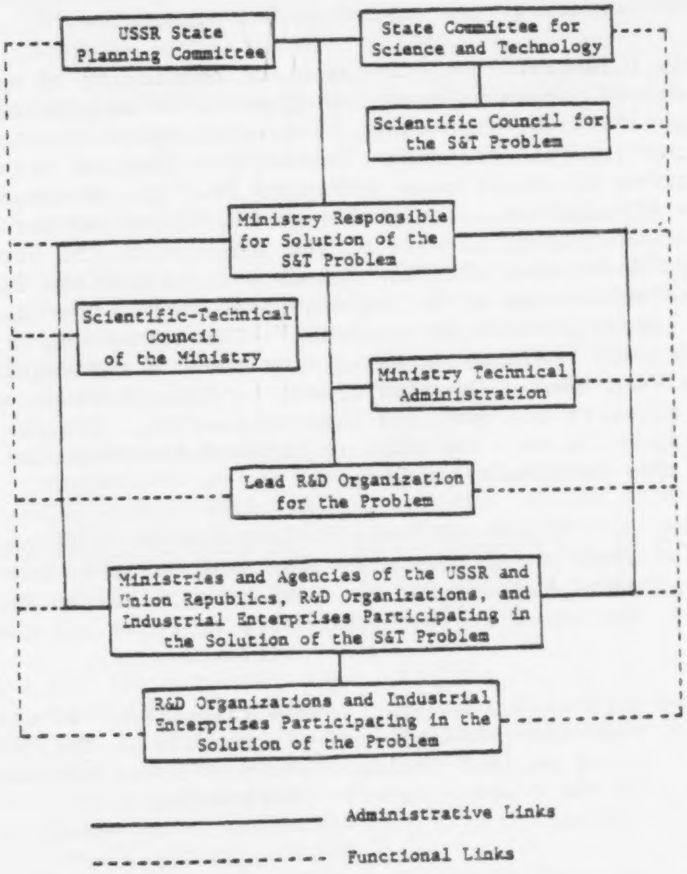
By their nature, basic S&T problems are large-scale, complex science policy efforts. The 246 problems in the Eighth Plan, for example, were broken down by the lead agencies into over 3000 assignments and projects and distributed to appropriate performers. The USSR Ministry of the Chemical Industry, for example, acted as the head ministry for 14 basic problems. R&D organizations and production units from more than 20 different ministries and departments were enlisted to work on them. At the same time, R&D facilities of the Ministry of the Chemical Industry participated as coperformers in nearly 150 projects for 51 problems under the auspices of 27 ministries and departments. Similarly, the USSR Ministry of Heavy, Power, and Transport Machine Building was responsible for solving 10 basic problems in which 23 other ministries took part. This ministry, in turn, worked on more than 240 projects dealing with different priority problems for which other ministries were in charge. In total, more than 65 all-union and union-republic ministries and agencies as well as over 350 performing organizations were involved in the activity related to this select list of problems. Some problems alone had as many as 50 or more institutional participants.[107]

The overall magnitude of effort remains about the same for the current 200 basic S&T problems. The total number of ministries and departments has climbed to over 70 while the number of performing establishments exceeds 400. With the transfer to more comprehensive work programs that extend through the innovation stage, the average number of organizational actors engaged on a given problem has grown. In addition, the USSR Academy of Sciences is involved on more than half of the 200 programs. About one-third of the basic problems also entail the participation of various East European states who are members of the Soviet-led Council for Mutual Economic Assistance.[108]

While the GKNT has a central role in establishing methodology for program formulation, in approval of draft plans, in authorization of funding, and in monitoring implementation, the branch ministry or organization selected as the lead agency is accorded primary operational authority and responsibility. The lead agency drafts the plan or work program for the problem, distributes specific assignments, arranges for financial and material support, and accepts the completed work from the various performers. In preparing the plan, the head ministry creates a commission of experts from various organizations which works in close collaboration with the scientific-technical council and the technical administration of the ministry as well as the R&D facility selected by the ministry to be the lead scientific organization for the problem. Through the expert commission, the ministry sets preliminary assignments, determines possible performers, including organizations under its own jurisdiction and subordinate to other ministries to whom certain portions of the work can be contracted out, and fixes approximate deadlines for implementation. These are then sent to the appropriate ministries and agencies which, directly with their R&D units, consider the possibility of meeting the targeted technical goals within suggested time and cost constraints. Some performers come back with counterproposals regarding deadlines, financing, and technical criteria. To settle unclear issues and to facilitate final agreement, the head ministry organizes bilateral and multilateral discussions. Any disputes that cannot be resolved by interagency bargaining are arbitrated at the GKNT. The final draft version of the plan or program is also sent to the GKNT for adjustment and approval. The organization of work on a basic S&T problem is illustrated in Figure 10-4.

One issue which is still not settled is the extent to which the lead agency can impose its authority over the facilities of another ministry in the event

FIGURE 9-4 ORGANIZATION OF R&D FOR THE SOLUTION OF AN IMPORTANT S&T PROBLEM


USSR State Planning Committee
State Committee for Science and Technology
Scientific Council for the S&T Problem
Ministry Responsible for Solution of the S&T Problem
Scientific-Technical Council of the Ministry
Ministry Technical Administration
Lead R&D Organization for the Problem
Ministries and Agencies of the USSR and Union Republics, R&D Organizations, and Industrial Enterprises Participating in the Solution of the S&T Problem
R&D Organizations and Industrial Enterprises Participating in the Solution of the Problem
Administrative Links
Functional Links

Source: "USSR Short Answers to US Questions," p. 17.

of conflict between program and branch assignments. Clearly, the authorities attempt to preempt such occurrences by requiring that program assignments be fully incorporated in branch and establishment plans. Presumably, this is an area where the authority of the GKNT can be exerted. Interestingly, one of the developments in the transfer from coordination plans to programs is enhancement of the role of the GKNT. Where a single ministry does not dominate in a program, the State Committee can assume the responsibility of project distribution and direction. Examples of such areas among the current 200 programs are computer technology and environmental protection.[109]

To illustrate both the size and complexity of such plans and programs, it is of interest to recount in some detail the experience of developing the advanced thermo-electric turbine. Each of the involved organizations is represented in Figure 10-5 by administrative affiliation. The prototype T-250/300-240 turbine was created as part of the solution to the problem, "To Develop and Take Measures to Ensure the Further Development of Centralized Heat Supply for Cities and Industrial Enterprises." The latter was one of the 246 basic S&T problems included in the Eighth Five Year Plan. The lead agency in this instance was the Ministry of Power and Electrification. The following tasks were included in the coordination plan for this particular project:[110]

No.	Nature of Tasks	Responsible Performer
1.	Issuance of the technical tasking for the design of the turbine[a]	The scientific-technical council of the Ministry of Power and Electrification
2.	Examination and approval of the preliminary project design of the turbine installation[b]	The scientific-technical council of the Ministry of Power and Electrification
3.	Approval of the technical project design of the turbine[c]	The scientific-technical council of the Ministry of Power and Electrification

4.	Outfitting the primary test bench for the assembly and testing of the turbine	The Urals Turbine Motor Plant (UTMZ) and the Ministry of Construction of the RSFSR
5.	Building the prototype of the turbine generator	UTMZ
6.	Manufacturing the feeder turbine pump for the turbine installation	The "Ekonomayzer" Plant and the Kaluga turbine plant
7.	Constructing the test stands for full-scale trials at the Sredne-Urals combined heat and power supply station	The USSR Ministry of Power and Electrification
8.	Assembly of the primary and auxiliary equipment for the Mosenergo electric power station	The Mosenergo electric power station, the Mosenergomontazh trust, UTMZ, and the Taganrog boiler factory
9.	Conducting start-up operations and testing the blocks with the T-250/300-240 turbine at the Mosenergo electric power station	The National Trust for the organization and rationalization of regional electric power stations and systems (ORGRES), Mosenergo, UTMZ, TKZ
10.	Checking the vibration condition of the rotors, stresses in the vanes, temperature fields and transferences under different conditions of turbine operation, and checking the system of control and oil supply, the economy of the tur-	ORGRES, Mosenergo, the All-Union Thermotechnical Institute, UTMZ, TsKTI

bine generator, and characteristics of the heat exchangers in different operating regimes

[a] The technical tasking is compiled by the organizations that order the equipment for the manufacturer and contains all of the basic requirements of the consignee: unit power, basic steam parameters (pressure, temperature); parameters of the extracted steam (pressure, temperature, amount), the magnitude of vacuum, assigned temperature and amount of cooler water, specific expenditure of heat per generated kilowatt hour, etc.

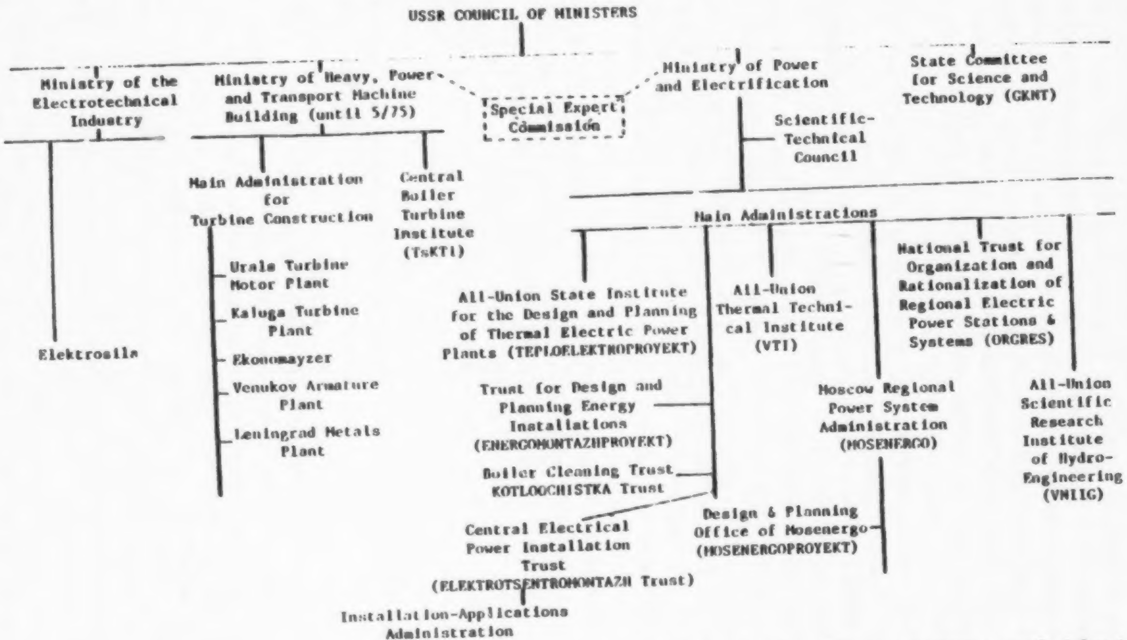
[b] The preliminary project design is compiled by the manufacturer of the equipment and serves as the basis for developing several variants of the ordered turbine. The elaboration of several variants is required for the final choice of the turbine by the consignee.

[c] The technical project design serves as the basis for the final development of the thermal and design system of the turbine and is done in accord with the approved draft design based on the variant selected by the consignee. In the technical design all of the basic qualitative indicators of the turbine are finally refined: the specific flow rate of heat, vacuum, internal efficiency of the cylinders, etc. The technical design is examined by experts of the consignee and is approved by the latter. The technical design also determines the manufactured price of the turbine and is the basis for drafting the working blueprints and other technical documentation of the plant which is manufacturing the turbine.

Each task was also divided into separate work stages and projects.

Later, in the course of installing and adopting the turbine it became necessary to make certain changes both in the design of the turbine and in the thermal

FIGURE 9-5 ORGANIZATIONS INVOLVED IN THE DEVELOPMENT OF THE T-250/300-240 THERMAL ELECTRIC TURBINE


USSR COUNCIL OF MINISTERS
Ministry of the Electrotechnical Industry
Elektrosila
Ministry of Heavy, Power- and Transport Machine Building (until 5/75)
Main Administration for Turbine Construction
Urals Turbine Motor Plant
Kaluga Turbine Plant
Ekonomayzer
Venukov Armature Plant
Leningrad Metals Plant
Central Boiler Turbine Institute (TsKTI)
Special Expert Commission
Ministry of Power and Electrification
Scientific-Technical Council
Main Administrations
All-Union State Institute for the Design and Planning of Thermal Electric Power Plants (TEPLOELEKTROPROYEKT)
Trust for Design and Planning Energy Installations (ENERGOMONTAZHPROYEKT)
Boiler Cleaning Trust KOTLOOCHISTKA Trust
Central Electrical Power Installation Trust (ELEKTROTSENTROMONTAZH Trust)
Installation-Applications Administration
All-Union Thermal Technical Institute (VTI)
Moscow Regional Power System Administration (MOSENERGO)
Design & Planning Office of Mosenergo (MOSENERGOPROYEKT)
National Trust for Organization and Rationalization of Regional Electric Power Stations & Systems (ORGRES)
All-Union Scientific Research Institute of Hydro-Engineering (VNIIG)
State Committee for Science and Technology (GKNT)

Source: Adapted from the case study by V. I. Vodichev et al, "Development and Adoption of Combined Heat and Power Supply Turbines with a Capacity of 250,000 Kilowatts."

system of the generator. In general, the changes fell into three groups. The first group included questions involving modifications in the technical documentation for the working design of the turbine generator. The answers to these questions, for the most part, were handled by the electric power station in collaboration with the organizations that helped install the equipment and put it into operation. Usually, by decision of the Chief Engineer of the electric power station or the Moscow Regional Power System Administration, a group of specialists was set up to handle particular problems. The group included representatives from the design, layout, assembly, scientific research, and other organizations, as well as the manufacturers of the primary and auxiliary equipment. After this group of experts arrived at a decision, the general designer made the appropriate changes in the operating blueprints and the consignee issued an order to the assembly and installation organizations to carry out the work.

The second group of changes included technical decisions regarding alterations in certain components of the turbine installation. Responsibility for solving these matters lay primarily with the manufacturers, who supplied the required new parts and attachments.

The third group of changes included problems that were first identified during operation and layout, involving aspects in the operation of the turbine installation that were not noted earlier. Here the ministries of the consignee and of the equipment manufacturer organized special expert commissions to address the problems. One of the most serious difficulties that arose during the initial period of installing and operating the turbine concerned poor vibration stability of the turbine. In this instance, a decision was made by the Scientific-Technical Council of the Ministry of Power and Electrification, with the approval of the Ministry of Heavy, Power, and Transport Machine Building, to create a special expert commission to tackle the problem. Representatives from participating organizations in both ministries took part in the work of the commission. The recommendations of the latter were examined and approved by the Scientific-Technical Council of the Ministry of Power and Electrification. Finally, the two principal ministries involved made a joint decision on the matter, which facilitated its solution in a relatively short time.[111] The whole process illustrates the role of expert commissions and the place of bilateral and multilateral consultation in Soviet R&D decision making, and especially in the distribution and coordination of tasks.

Not all coordination plans were as well formulated and organized as the above example, however. Conceptualization of problems was frequently inadequate so that the coordination plans were "a hodgepodge instead of a network of logical systems."[112] Some plans were unwieldy and included activity that was not relevant to the problems being addressed. Other plans consisted of small projects inappropriately named "basic problems." Various stages of work and projects were not correlated. Many of the plans were not oriented to goals. Some had no fixed objective at all. Ambiguity in defining goals and assigning tasks led, in turn, to gaps and incoherence in program development, which resulted ultimately in the delays, cost overruns, and duplication noted earlier. As M. A. Gusakov concluded, "In essence, the mix of tasks for a basic problem is chosen to a large extent by intuition."[113]

The replacement of coordination plans by S&T programs seeks to remedy these deficiencies. Much more than before, the accent is on the actual introduction of R&D results into the economy. Coordination plans usually reached only to the stage of creating prototypes of new items, trying out new processes, or issuing recommendations for series production. However, some new machines and designs were held up for years at the recommendation stage. The new programs emphasize bringing the R&D forward through the innovation phase. Hence, more than 60 percent of the machines, equipment, and instruments as well as 80 percent of the new processes, materials, and data processing systems being developed in connection with the 200 basic S&T problems in the Tenth Plan are "programmed" to be put into production or use. Timetables are fixed for intermediate work stages as well as for final completion. The design and construction of pilot plants, and the creation of industrial facilities assigned primary responsibility for the manufacture of new items, are also stipulated. The old coordination plans rarely specified these assignments. A program, then, is a more comprehensive and systematic grouping of assignments than a "coordination plan."[114]

In addition, the procedure for drawing up S&T programs has changed. In the past, coordination plans were prepared mainly by the lead scientific organizations and the technical administrations of the ministries; these were not always coordinated with the other functional divisions of the ministries. To integrate more effectively science and economic planning, the process of drafting S&T programs has been made more of a collaborative effort involving the entire ministerial staff. Comparing the old system of plans with the new system of programs, Nolting concludes, "Although both combined and coordinated all of the projects relating to a given problem, the redesignation is more than a change in name."[115]

At the branch level program-type planning, called "continuous" planning, has been implemented experimentally in a few ministries. Such planning is done in concert with a special form of financing R&D, the Unified Fund for the Development of Science and Technology, which consolidates the funding of all stages of the innovation cycle. A lead research institute, design bureau, association, or enterprise is designated, and all work stages are implemented by an intraministerial contract called a work order. The structural similarity to interbranch programs at the all-union level is apparent. Because such plans are closely tied with implementation and incentive and financial policy, discussion of them is postponed until the next chapter.

In summary, the importance of multiagency programs is attested to first by the criticality of their themes and the significant amounts of resources which they command. At the same time, formal procedures for multiagency planning techniques are a relatively new development, still clearly undergoing modification. Multiagency programs offer great potential for improving coordination across organizational lines, but they made create significant problems if merely superimposed on the traditional branch planning structure. Soviet authorities recognize the importance of careful integration of program and branch assignments to avoid sending conflicting signals to the performing facility. Evidence is still fragmentary concerning evaluation of the scope of application and management of multiagency programs; therefore, it is unclear whether the significant benefits of such programs are being fully realized. It is also too early to tell the extent to which the shift from coordination plans to integrated programs overcomes some of the faulty systems planning and management of the past.

THE DECISION TO IMPORT TECHNOLOGY

Though the Soviet Union has long imported technology and machinery from abroad, the decision to acquire foreign technology was not made until recently an explicit and integral feature of R&D policy planning. A number of Soviet surveys conducted in the mid-1960s disclosed that few research institutes possessed, much less used, comparative data on foreign technology and Soviet products.[116] During the spring meeting of the USSR Academy of Sciences in 1965, it was noted that many of the items included in the plan for new technology and slated for development by 1970 could, in fact, already be bought from the United States, Japan, and Great Britain.[117] At this time little attention was given to the purchase of foreign patents and licenses or, for that matter, to the protection of Soviet inventions abroad. Only in July 1965 did the USSR begin to adhere to the Paris Convention for the protection of international property. In general, the idea that it may be cheaper and more effective to borrow technology than to develop it domestically is still somewhat novel for Soviet decision makers. As Robert W. Campbell points out, "They have surely often thought it would be convenient to solve some problem with foreign equipment, but the notion of a conscious policy choice to be made routinely and systematically is probably still not very common."[118]

Three factors in particular have contributed to this situation. First, the planning of R&D has been oriented to building up S&T potential that can serve as a basis for the solution of future problems. The planning of technological innovation and utilization, on the other hand, has been geared to solving current production tasks. The two spheres of activity have generally been decoupled, and each has proceeded more or less on its own. Second, the time factor and the "cost" of time have not figured prominently in R&D decision making. Only since the late 1960s have efforts been made to extend the time horizons of planners and to make the five-year plan rather than the annual plan the basis for S&T problem-solving. Third, the Soviet R&D establishment has been inward-looking and has tended to display a "not-invented-here" sentiment. As a recent article in the Gosplan journal noted,

> There are more than a few examples where ministries and departments try for years to solve through their own efforts problems that have long been solved in other countries. In a number of cases the leaders and specialists of certain scientific organizations consider the decision to buy licenses as testimony regarding their own S&T inadequacy. But only a precise and competent opinion as to how each item and process compares with the world standard and to its prospects for further improvement should be an important consideration in the decision to accelerate our own research and development or turn to the acquisition of a foreign license.[119]

However, a former Soviet scientist now in Israel, Professor M. Perakh, writes that there has been widespread illicit use of foreign patents and know-how. Soviet scientists often use, he claims, Western patents and other data as a basis for research proposals, without acknowledging these sources to financing bodies or to their administrative superiors. The R&D then replicates results already achieved abroad without superior authorities or potential Soviet users of the R&D being aware of this fact.[120]

In any case, the thrust of official policy in the 1970s was increasingly to make foreign technology acquisition an explicit variable in R&D policy planning and world standards a specific criterion for evaluating and improving Soviet R&D performance. This applies particularly to priority projects. Thus, the division of the plan that deals with the basic S&T problems includes a listing of the assignments that are to be carried out on a collaborative basis with other CEMA countries and those that are to be completed by means of foreign patents and technology. We have also seen that the "technical level charts" developed for each priority problem require comparative evaluations of the projected new technology with the best domestic and foreign technology.

In addition, a special division devoted to the sale of Soviet patents abroad and to the purchase of foreign patents and technology has recently been added to both the annual and five-year plans for development of science and technology. This division fixes five year quotas for the receipts of foreign currency from sales of Soviet patents for the USSR as a whole, for the republics, and for each ministry. Provisions are established for each ministry to give technical assistance to foreign firms in the assimilation of technologies obtained under Soviet patents and to deliver special equipment and materials for startup of production. The plans for purchasing foreign licenses and technology stipulate the kinds of technology to be imported and the amount of foreign exchange required to pay for it. Ministerial plans spell out in detail the foreign firms to be dealt with, the types of patents and models to be acquired, the equipment and materials needed for the assimilation of foreign technology, requirements for capital construction, the R&D performers and industrial facilities to be assigned to the adaptation and installation of the imported technology, legal rights and obligations in the use of this technology, and the estimated economic return from its adoption and diffusion. At the same time, a determination must be made of what scientific R&D projects should be terminated after purchase of a foreign patent.[121]

The extent to which these new procedures are adhered to and the overall impact of changes in import policy on the planning process are impossible to assess from available information. Calculation of the economic effectiveness of Soviet technology, we have seen, is still fraught with many problems and deficiencies. Methods and criteria for evaluating the effectiveness of foreign technology and the comparative advantage of borrowing from abroad or building domestic capability are only beginning to be developed. According to one Western authority, "So far it appears that planning calculations of this type have had little role in the actual planning of exports and imports."[122] In addition, decisions to import technology are still limited to high priority problems and projects. For the bulk of Soviet R&D, the inside-outside choice simply does not arise. Borrowing is not a real option.[123]

More generally, these changes in R&D policy planning have coincided with considerable expansion of Soviet participation in international trade and technology transfer. Reasons for such expansion are typical: a combination of certain pressures which induce international cooperation, such as global environmental problems, and the standard benefits which accrue to all who take part in the international division of labor in science and technology.[124] Increasingly, Kremlin authorities have come to realize that it is expensive--and not necessary--to reinvent the wheel and to be self-sufficient in all areas of science and engineering. They have also come to regard the importation of modern equipment and foreign know-how as an active force to improve the functioning of the Soviet economy and to accelerate its technological modernization, and no longer as just a subsidiary source for supplementing domestic production.[125]

The USSR is entering the world market to supply as well as to acquire advanced technology. Increased imports of technology have generated the need to expand Soviet export capacity in order to raise revenue to pay for imports. Soviet leaders are also convinced that they will be at a disadvantage until they succeed in selling substantial amounts of machinery and equipment to Western countries, in addition to the raw materials and fuels which now make up the bulk of Soviet exports.[126]

Thus, the decision to borrow and the types of technology imported are heavily influenced by foreign exchange considerations. The oil and gas industry, for example, has been one of the largest users of borrowed technology, and Campbell notes that "part of the rationale must surely be the combination of an urgent pressure to expand output with a realization that this expansion of output itself generates the foreign exchange."[127] Similarly, in the coal industry, he adds, recent decisions to import power shovels and large vehicles for open pit mining appear to be strongly motivated by their role in assisting in the expansion of exports. Other foreign equipment and machinery, like automotive technology and some computer-based systems, are acquired in part, it appears, to increase Soviet capacity for producing high quality manufactured goods saleable on world markets. On still another level, foreign trade considerations are also important in determining some of the priority S&T problems. One of the recent 250 basic problems, for example, focused on the development of super tankers with a capacity of more than 100,000 tons.

Finally, it may be noted that Soviet policy on technology transfer has itself undergone change in recent years. Authorities have come increasingly to realize that effective transfer requires a broad, continuous flow of people and ideas rather than just products. Thus, they have begun to adopt a systems approach to transfer, absorption, and diffusion that "involves not only machinery and plants but also training, management, and foreign expertise or know-how."[128] While the more traditional style--limited, once-off machinery purchases, a good deal of literature scanning, imitative development, and reverse engineering--probably continues, it is being supplemented by, if not giving way to, the new systems-oriented policy.[129]

Briefly, Soviet procedure for technology acquisition is as follows. Research, design, and production facilities submit their requests to parent ministries, which maintain special functional administrations to handle imports and exports. The establishment may have its own reserves of foreign currency to pay for the acquisition, or it may apply for ministry or central funds. In the latter case the requests are examined particularly carefully. Certain of the requests, in turn, are forwarded to central management agencies. Following selection of the desired commodities and technologies, arrangements are made by the responsible organs. The importation of products is handled by foreign trade associations organized by product line and subordinate to the Ministry of Foreign Trade. Gosplan and Gossnab are involved because imports must be accounted for in production and supply plans. The importation of licenses and other "disembodied" technology is handled by Litsenzintorg, also subordinate to the Ministry of Foreign Trade. The GKNT is heavily involved in all decisions to import foreign technology. Expected imports are incorporated in research, development, and implementation plans in the same way as domestic technology. In general, the whole foreign technology acquisition process has been highly centralized. Only in recent years have efforts been taken to break the tight monopoly of the Ministry of Foreign Trade and to encourage greater initiative by the ministries and lower-level facilities.

THE STRUCTURE AND CONTENT OF R&D PLANS

The previous discussion has described steps and stages in the Soviet planning process at all levels in the hierarchy. The culmination of the process is of course the operational plan which, as noted, is the fundamental mechanism for managing and coordinating the activities of economic units. Indeed, the deterministic and official character of such plans needs to be emphasized. Their approval is not purely symbolic; they are formally passed into law. While today sanctions imposed when plans are not fulfilled are rarely more severe than monetary penalties, the penalties in foregone bonuses are large, and managerial careers are jeopardized.

Virtually all establishments and management organs in the Soviet Union draft annual and five-year plans, and most significant entities develop long-range plans of varying durations, generally corresponding to the nature of the subject matter and the forecasting methods employed. For example, in the engineering industries in which tasks are fairly "concrete" and technology may change rapidly, long-range plans may be restricted to two years; for Academy and MinVUZ facilities long-range research plans may be devised for 15 year periods. While the subject matter in the plans of the respective hierarchies differs, all sets of plans generally exhibit increasing detail or "concreteness" and a growing orientation to economic application with the shortening of the time horizon.

In the hierarchy of plans the state plan for development of science and technology is of course supreme. The operational versions of this plan, the five-year and annual plan, contain the following chapters:

1. Assignments for solving the basic S&T problems
2. Work programs for introducing new types of products and technological processes into production

3. Production assimilation of new industrial products

4. Introduction of advanced technological processes and mechanization and automation of production processes

5. Sale of Soviet patents abroad, purchase of foreign patents and models of new products, and their utilization in the USSR national economy

6. Introduction of computer technology into the national economy

7. Establishment of state standards governing the most important types of products and metrological support of the national economy

8. Introduction of scientific organization of labor

9. Basic indicators of the technical and economic level of production and output

10. Financing of scientific research

11. Training of scientific personnel and science teachers.[130]

The content of each chapter is self-explanatory. Certain chapters are concerned with a general category of R&D, such as the introduction of new products; some pertain to a special category, such as licensing or the application of computer technology; and still others focus on the establishment of operating and evaluative criteria, such as standards and technical indicators, which support the remaining chapters. In addition, the universal correspondence between physical and financial flows is exemplified by inclusion of the financial plan.

At the stage of the intermediate level management organs, plans become more concrete. Plans incorporate targets specified in chapters of the national plan, but are organized differently in relation to the character of the R&D in the hierarchy. In the Academy and university systems, the program or project is the centerpiece of the plan, with most indicators concerned with measures of inputs (e.g., wage funds) and the scheduling of work. Emphasis is also placed on specifying the ultimate user of results, and calculations of economic return are required where possible. Plans in industrial ministries are oriented to the application and introduction of R&D results. Branch plans contain divisions that correspond to and derive from the macro state plan divisions for the assimilation of production of new types of products and the introduction of new processes. There are also divisions for improving the stock of equipment, the organization of production, and the quality of output. The annual plans of the branch ministries also include a special division for scientific research and test-design, which lists the R&D assignments under the special programs for solving the basic S&T problems.

At the performer level in the hierarchy, the structure and content of plans correspond to the orientation of the superior organization's plan and the character of R&D activity. Independent research and design facilities draft five-year and annual "thematic" or project plans in which the central object is the research project. Nolting observes, "There are no standard methods and forms for drawing up project plans among scientific organizations that are under different ministries and perform different kinds of work, but there is a basic procedure and set of requirements."[131] In general, project plans have two main sections: one for R&D conducted within the facility, the other for assimilation of finished R&D to be transferred to the appropriate production organizations with the advice and assistance of the scientific facility.[132] Information in the yearly projects plan includes the following: the general volume of scientific research and experimental design work for the plan year; the expected economic return; the periods for completion of work on each project;

estimated costs; the sources of financing; the rationale for including the work in the plan; and the designation of the industrial enterprise to receive the R&D results for application.[133] The emphasis on defining ultimate uses is apparent and is to some extent a new element, at least in degree. Along with the thematic plan, a "calendar" plan is developed which schedules work by stages and designates performers and inputs.

In the production enterprise, the "plan for increasing the efficiency of production" or, as it is generally called, "the new technology plan" carries through the applied orientation reflected in the ministry's plan. In the past, five-year plans of this sort were drawn up only in the larger enterprises or production associations. With the Tenth Five Year Plan, however, they have apparently become mandatory for all enterprises.[134] The annual enterprise new technology plan, which has been a basic feature of Soviet planning since the late 1920s, is drafted in minute detail and contains the following subdivisions:

1. Assimilation of new types of products and improvement of the quality of production

2. Introduction of advanced technological processes and mechanization and automation of production

3. Introduction of scientific organization of labor

4. Improvement of the organization, planning, and management of production

5. Scientific research and experimental design

6. Basic indicators of the technical and economic level of production and output

7. Protection of the environment and rational use of material resources.[135]

In each subdivision the documentation required on a project basis is extensive and similar in scope to the other examples already cited.

THE PLANNING SYSTEM AND ITS PARTS

In principle, these numerous sets of plans, differentiated along temporal and organizational lines as well as hierarchical branch and functional program lines, form an internally consistent and well integrated "system" of plans regulating the research-to-production cycle. In practice, however, there are many "holes in the whole," and coordination falls far short of its target. Given the scope and comprehensiveness of Soviet planning, this is not surprising. Perfect coordination is unlikely in any system, partly because of the unpredictability of the results of scientific research and development. But as Nolting observes, "Soviet R&D planning has been poorly coordinated even if judged by standards less than ideal."[136]

Only since the late 1960s, it may be recalled, have Kremlin authorities pursued a policy of integrated systems planning of R&D, innovation, and production. Even today such a policy is applied, for the most part, only in high priority projects. Soviet planning is generally still of two kinds: "compilation planning" and "implementation planning." The former involves primarily a listing of assignments while the latter entails more systematic and deliberate efforts to specify targets, to assign responsible performers, and to coordinate tasks. Implementation planning is limited primarily to the interbranch S&T programs of national priority and to the continuous plans in certain branch ministries. Compilation planning remains the predominant form with results that are less than optimal. Again Nolting provides the best description of the system:

> RDI [research-development-innovation] planning has often amounted to little more than

> a simple listing of projects to be carried out without relating them to broader purposes. In large part the projects are suggested by lower units in the planning chain and reflect the interests and expertise of performing organizations. Many such projects are reported to be trivial and marginal in their technological benefits. The proposals submitted by lower echelons are not always properly screened and those accepted are not worked into coherent plans consistent with the general technological directions of the higher planning echelons. In other words, RDI plans tend to be accumulations rather than syntheses.[137]

The demand for techniques to view projects in a total systems perspective is clearly felt and provides the impetus behind the systems movement in Soviet science policy today. Network planning and programming methods enable decision makers to perceive projects more broadly as systems and to depict the interrelationships among tasks to be performed. In general, though, these are still new and untested tools. "Many deficiencies in planning scientific and technical progress," explains one Soviet science policy expert, "are rooted in the lack of appreciation of programming methods and in the narrow front of their application."[138] Even for basic S&T problems, systems planning is still very much an evolving technique. A deputy director and research analyst at Gosplan's Central Scientific Research Institute of Economics acknowledge, "We have still not accumulated sufficient experience in drawing up long-term S&T programs. It is possible to say that the formulation of programs in most cases is still in the formative stage."[139] On the branch level, too, progress has been slow and limited in developing program-type planning. By 1974 only three ministries had transferred to the system of continuous planning, though by 1978 this number had climbed to 11. The rest continue to plan R&D largely around separate organizations rather than broad programs.

On another level, complaints continue that R&D plans are inadequately coordinated with production plans. Organizationally, these two spheres of planning remain compartmentalized in different functional administrations within the ministerial structure. The creation and application of new technology is partitioned off from general economy activity.[140] Overall, the planning process and its outcomes continue to reflect the fact that science and industry are still largely separate worlds in the Soviet Union.

Centralized financing also continues to be deficient as an integrating instrument in R&D planning and management, especially of major interbranch projects. In the Eighth Five Year Plan, budgetary funds for a given coordination plan were allocated through standard channels to all the participating ministries. Such a procedure resulted in multiple sources of funding and fragmented administration of plans. Accordingly, the procedure was changed in the Ninth Plan, and the entire budgetary allocation for a coordination plan was assigned to the lead agency in charge of the plan. All nonbudgetary sources of financing the plan were also placed under control of the head ministry , which was authorized to distribute funds to individual performers in other ministries through contracts.[141] This is still the practice today.

Nonetheless, problems remain. Technically, the allocations for basic S&T problems cannot be directed to other projects without approval of the GKNT; they must be used according to the principle of "the money to the problem." In practice, however, these funds are diverted and used sometimes for other purposes. "Centralized financing is often replaced by decentralized financing," asserts M. P. Ring. Criticizing the existing method of aggregate bloc financing, he suggests that a system of "incremental financing" be introduced for these expensive and long-term programs that would relate budgeting more closely to actual results and tie decision making more effectively to cost, uncertainty, and risk.[142]

Finally, integration of plans and programs is impeded by limitations and gaps in the analytical base underpinning science policy. To be sure, some progress has been made over the past decade in both refining and broadening the criteria for deciding problems of choice. Awareness of the parameters of "time" and "cost" has particularly increased in R&D decision making. The principle of "better late than never," which prevailed largely in the past, is being replaced by "either on time or not at all" as the issue of obsolescence becomes increasingly important. At the same time, technical progress "at any price" is being questioned and rejected, at least in some science policy circles, as the squeeze on resources grows. More and more, available means determine possible goals; alternative futures have to be weighed in terms of their comparative costs and benefits. In addition to the economic dimensions of cost, the social and ecological ramifications of technological undertakings are beginning to be weighed in the decision calculus. More scientific forecasting and long-range strategic planning are perceived as imperative. Much as in the West, the whole thrust of recent Soviet planning, forecasting, and goal-setting in the area of science and technology is to reduce uncertainty, to anticipate contingency, and to provide a greater sense of purpose and direction.

The growing complexity of contemporary problems in science, technology, and production has exposed the inadequacy of traditional planning methods and evaluative indicators. Today the articles manufactured by any branch are so diverse and the technologies for their production so numerous that evaluating the activity of a modern enterprise according to prevailing gross output and simple aggregate indices is "like judging a painting by the weight of the paint used or the area of the canvas it covers," noted a recent article in Pravda.[143] At the same time, the inadequacy of technique applies to the new methods of planning as well as to the old. The former are still in the process of evolution as the search continues for more sophisticated ways to integrate complexity and to respond to the new claims of efficiency and quality. Adequate procedures have not yet been found for calculating the "cost/benefit ratio," "economic return," and "social effectiveness" of R&D. The new technical indicators policy is still in the experimental stage.

Hence, rough rule-of-thumb methods are likely to dominate S&T decision making for some time. They are indeed an inevitable and integral feature of managing multiparticipant decision analysis in all societies. Even the arrival of more "powerful" modern planning techniques will not appreciably alter the basic political character of the Soviet decision process. As a former Soviet planning specialist now in emigration recently observed about the system, "The iterative process, balancing, 'coming to agreement' does in fact occur but not on paper, not in calculation, but in life itself."[144]

FOOTNOTES

1. O. I. Larichev, "Dostoinstva i nedostatki sistemnogo podkhoda k planirovaniyu i upravleniyu nauchnymi issledovaniyami, vklyuchaya analiz 'stoimost-effektivnost'"(Merits and Defects of the Systems Approach to Planning and Management of Scientific Research including Cost-Effectiveness Analysis"), p. 4. Soviet Side of the Joint Soviet-American Working Subgroup on Planning and Management of Scientific Research and Development. Unpublished (draft) paper, 1976.

2. Louvan Nolting, The Planning of Research, Development, and Innovation in the USSR, U.S. Department of Commerce, Foreign Economic Report No. 14 (Washington, D.C., 1978), p. 1.

3. See Yu. M. Kanygin, Nauchno-tekhnicheskiy potentsial (Problemy nakupleniya i ispol'zovaniya) (Novosibirsk: Nauka, 1974), pp. 157-159, 179-182 and also his Nauchno-proizvodstvennyi tsikl: Voprosy teorii i organizatsii (Novosibirsk: Nauka, 1971).

4. Yu. Kanygin and S. Kostanyan, "Nauchno-proizvodstvennyi tsikl," Voprosy ekonomiki, 12 (1976), p. 62.

5. Louvan E. Nolting, Sources of Financing The Stages of the Research, Development, and Innovation Cycle in the USSR, U.S. Department of Commerce, Foreign Economic Reports No. 3 (Washington, D.C., 1973), p. 3.

6. V. Yu. Budavey and M. I. Panova, Ekonomicheskiye problemy tekhnicheskogo progressa (Moscow: Mysl', 1974), p. 19.

7. N. M. Oznobin and A. S. Pavlov, Kompleksnoye planirovaniye nauchno-tekhnicheskogo progressa (Moscow: Mysl', 1975), pp. 155-156.

8. L. Sh. Gaft and Ya. S. Krasov, Podsistema uprav-

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9. Leonid Kantorovich, "Economic Problems of Scientific and Technical Progress," *Social Sciences*, 3 (1976), p. 87.

10. S. Golosovskiy and G. Yeremenko, "Measuring the Effectiveness of Scientific and Technical Progress," *Voprosy ekonomiki*, 12 (1975), pp. 142-145. See also B. Zaytsev, "Voprosy ucheta zatrat na issledovaniya i razrabotki," *Vestnik statistiki*, 1 (1977), pp. 10-14.

11. Gaft and Krasov, *op. cit.*, p. 53.

12. B. Z. Milner, "Sovershenstvovaniye organizatsionnykh struktur upravleniya," in *Sovremennye metody upravleniya narodnym khozyaystvom* (Vilnius: Litovskiy Nauchno-Issledovatel'skiy Institute Nauchno-Tekhnicheskoy Informatsii i Tekhniko-Ekonomicheskikh Issledovanii, 1974), pp. 4-5.

13. Statement by N. P. Lebedinskiy to a group of American specialists visting the USSR in the fall of 1974 as part of the Joint US-USSR Science Policy Working Group.

14. Milner, *op. cit.*, p. 4.

15. See, for example, I. P. Kozlov, V. P. Vorobyev, and A. S. Korotkov, "Voprosy metodologii analiza deyatel'nosti otraslevoy nauchnoy organizatsii," in *Problemy deyatel'nosti uchenogo i nauchnykh kollektivov* (1977), pp. 78-81 and Oznobin and Pavlov, *op. cit.*, pp. 148-149.

16. M. L. Bashin, *Planirovaniye rabot otraslevykh NII i KB* (Moscow: Ekonomika, 1973), p. 171.

17. M. G. Kolodnyy and A. P. Stepanov, Planirovaniye narodnogo khozyaystva SSSR (Kiev, 1975), p. 90.

18. Valuyev et al, "Unique Characteristics of the Financing of Science in the USSR," (Russian text), p. 43.

19. "Official" science expenditures in the USSR do not include outlays on (1) R&D performed by enterprise scientific subdivisions in most ministries; (2) development and testing of "industrial" prototypes under factory conditions; (3) scientific and technical assistance to and collaboration with enterprises by branch, academy, and VUZ scientific organizations; (4) R&D financed under special innovation funds in industry or under capital investments in economic branches; (5) the portion of VUZy R&D financed under the specific budgetary allocation for VUZy; and (6) probably some categories of military and space R&D. See Louvan Nolting, The Financing of Research, Development, and Innovation in the USSR, by Type of Institutional Performer, pp. 2-3.

20. Nolting notes that "These investments are not confirmed or allocated specifically as investments in science, but rather as investments attributed to pertinent economic branches, although the investments are monitored and audited by the State Committee for Science and Technology." See ibid., p. 26.

21. Ibid., pp. 17-19.

22. "Unique Characteristics of the Financing of Science in the USSR," p. 48.

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Science Policy in the USSR, p. 250.

26. Helgard Wienert, "The Organization and Planning of Research in the Higher Educational Establishments," ibid., p. 354.

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32. Pospelov, op. cit.

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35. Ibid.; Kushlin, op. cit., p. 138.

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38. Nolting, *The Financing of Research, Development, and Innovation in the USSR*, pp. 33-35.

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47. Ya. D. Gartsman and V. M. Ignatenko, "Sovershenstvovaniye planirovaniya nauchno-issledovatel'skikh rabot v ministerstvakh i vedomstvakh," in *Ekonomicheskiye problemy nauchno-tekhnicheskogo progressa v narodnom khozyaystve USSR* (Kiev, 1974), pp. 14-15.

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desyatoy pyatiletke," *Voprosy ekonomiki*, 11 (1976), pp. 47-55; Disson, "Primeneniye programmno-tselevogo metoda," pp. 74-75; "USSR Short Answers," p. 18.

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78. Cited in Nolting, *The Planning of Research, Development, and Innovation in the USSR*, p. 6.

79. Disson, "Primeneniye programmno-tselevogo metoda pri reshenii nauchno-tekhnicheskikh problem," pp. 81-82.

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89. M. P. Ring, "Problemnoye upravleniye v nauke: pravovyye aspekty," Vestnik Akademii Nauk SSSR, 7 (1976), pp. 15-16, 18.

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93. Ibid., pp. 52-58.

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X THE EXECUTION OF R&D PLANS AND THE UTILIZATION OF RESULTS

As we have seen, the R&D plan commits the research institute, design bureau, and production enterprise to a comprehensive and detailed set of technical and economic objectives. The annual plan, subdivided into quarterly and monthly targets, is the basic operational document. It has the force of law, and is the principal stimulus to implementation.

Although certain objectives are imposed by superior organs, and the plan must be approved in detail by superior authorities, the performer establishment manager does participate in plan formulation. The manager has a certain degree of autonomy, especially compared to earlier periods of Soviet history, but he still lacks one common ingredient of autonomy: flexibility. Even if the approval by superiors is merely *pro forma*, the manager is still committed to the plan for its duration. Only rarely are superior bodies inclined to permit alterations in annual plan targets. They discourage the raising and reducing of targets because such actions can reverberate and disrupt the economy. The plan is thus ambitious and inflexible: this consideration alone fosters conservatism and works against unpredictable activities like R&D.

In this chapter we look at control mechanisms and incentive systems used to put the plan into practice. In their detail and comprehensiveness, plans provide more than general directions for the performer establishment. Yet the manager still exercises discretion in decisions concerning how plan tasks can be accomplished. To aid the manager in selecting the most effective means of fulfillment, the state has created an organizational structure and a set of decision rules aimed at engendering strong effort and effectiveness. Such incentives as the size of expected bonus funds with plan fulfillment are also incorporated formally in plans, although these are derived mainly post facto by application of formulas to match indicators against actual establishment performance. Organizational, economic, and managerial mechanisms for plan implementation, like the plan targets themselves, should of course be internally consistent and move the establishment on the track desired by the central leadership.

In practice, however, the plan and the machinery for its execution frequently break down. The translation of scientific ideas into new products and processes becomes an obstacle course of endless delays and difficulties. During the 1960s losses due to the slow transfer of R&D results into use ran between six and eight billion rubles a year, or the equivalent of one-fifth of all funds allocated for innovation. For the period of the Seventh Five Year Plan (1959-1965) these losses amounted to about half of the total investment in scientific research and development. It is estimated that an additional five to six billion rubles can be saved annually if the time lag for innovation is reduced by just one year. Even now not more than 30 to 50 percent of completed R&D finds its way into production. The remainder is either not used at all or assimilated so slowly that it is already obsolete by the time of its introduction. In certain fields as much as 80 percent of finished R&D falls by the wayside without practical utilization.[1] Clearly, a major challenge facing Kremlin leaders today consists in formulating a science policy to encourage innovation and the utilization of S&T results.

MANAGING THE RESEARCH-TO-PRODUCTION CYCLE: AN OVERVIEW

Technological innovation in the Soviet Union at present is essentially a bureaucratic function, with situations referred upward through long organizational lines for resolution. Individual and institutional performers rarely collaborate directly. Most external transactions among organizations are managed through ministerial offices and departmental channels. A research institute or design bureau, for example, reports its results to a technical administration, branch glavki, or industrial association to which it is subordinate. The latter, in turn, decides on what should be the next phase of work, by whom, and where.

This structure impedes innovation in at least two important ways. First, the long approval route delays decisions and prolongs the research-to-production cycle. To create a new machine, for example, requires typically 25 approvals at different levels. To build a new technological system of 10 to 15 machines and mechanisms may require as many as 400 to 500 clearances.[2] In general these agreements are obtained sequentially and not in parallel.[3] Forward movement is constantly stalled by rounds of negotiation; by waiting for approval of reports by departmental and interdepartmental expert commissions or for the return of tests on prototypes; by the absence of supplies, equipment, and financing; by the need to find the right customer with the appropriate experimental base. Considerable time is spent on correspondence and on trips to ministries in pursuit of support for innovation. The path from conception to commercialization can be especially long and precarious if the technology entails new processes or products unrelated to established interests and activities or if it involves much interbranch negotiation. The effort devoted to gathering signatures of approval is due in part to statutory regulations. However, it also serves, Berliner explains, "as a device for limiting each organization's responsibility for its own stage of the work and for reducing one's vulnerability in the event of difficulties encountered in later stages."[4]

According to studies by the State Committee for Science and Technology it frequently takes as much time to secure agreements and to transfer documents from one organization to another as it does to conduct the necessary scientific development.[5] That is, the bureaucratic process of moving research results consumes as much time as the research and development process itself. Even excellent ideas must stand in line to be included in the work plan of the organization designated to conduct the next phase of the process. Such ideas, too, sometimes fail to pass the approval stage. Among the nearly 700 completed R&D projects proposed by the Siberian Division of the USSR Academy of Sciences for practical use between 1960 and 1970 but were not introduced, about 40 percent had become obsolete while waiting for higher approval.[6]

Second, the quality of decision making is reduced because the structure forces decisions to the highest levels away from the information and knowledge that are most relevant to deal with them. Each additional level distorts objectives and misdirects attention. The vision of individuals and managerial units is directed toward separate efforts rather than the overall enterprise, results, and performance. Structure and procedure also tend to focus attention on wrong issues, such as jurisdictional disputes, formal plan fulfillment, and the avoidance of risk. All along the line there is constant danger a project will lose momentum and fall into incompetent or unsympathetic hands.

These obstacles assume special importance in the branch ministries where the managers are appreciably less qualified than in the Academy system. Scientists themselves manage academic science, and it is not nearly as fragmented and hampered by departmental limitations as branch science. R&D in the ministries, on the contrary, is directed by people who are not scientists. "They themselves do not perform scientific research, and many of them have only a vague notion of how it is conducted."[7] To be sure, scientific and managerial competence varies across ministerial lines. In the defense-related sectors, such as the machine-tool and instrument-making, radio, and electrical equipment industries, R&D management is qualified, experienced, and forceful. It is much less so in long neglected areas like light industry, consumer goods, and local services. Here sometimes the technical administrations and coordinating departments of ministries lack specialists with any advanced scientific degrees. Some responsible staff even lack a higher education.[8] Nonetheless, many branch R&D organizations display great timidity toward their ministries. The studies they conduct are often pro forma exercises that fail to expose deficiencies in the development of the branch, much less in the leadership of the ministry.[9]

Generally speaking, the Soviet approach to structuring and managing innovation has been premised on an image of technology transfer that prevailed largely in the West until the early 1960s. According to this view, the transfer process is envisaged as "the passage of disembodied 'ideas and methods,' endowed with some quasi-independence in the manner of genes, from one state of existence or milieu to another." The underlying assumption is that technology is primarily "an assemblage of pieces of information which can be extracted or expelled from one sector of organized creativity and transposed to another to produce different outputs."[10] The whole process is reduced to clerical reporting, to a mechanical transmission of documents and routing of information.

As has happened in the West, this perception of technology transfer is being increasingly questioned and replaced by a more dynamic and systems view. One of the major Soviet discoveries about innovation in the 1970s, in fact, was the importance of the "management connection." The very phrase "research-to-production" cycle is said to be a misnomer because action throughout must be negotiated and mediated. It is better to speak in terms of a system of "research-management-production," to use the words of some Soviet analysts. Such phraseology, they note, conveys a more adequate image of this complex process. It also explicitly identifies and emphasizes the management function and linkage.[11] With gradual movement away from a strictly phase-dominant to a more process view of innovation, the need for a systems model of organization and management has become more and more apparent. Indeed, it is not too much of an exaggeration to say that the Soviet research-to-production cycle has been fundamentally unorganized and unmanaged. We return to this theme in chapter 12 on current issues and trends in Soviet science policy.

ORGANIZATION OF THE R&D CENTER

The criteria for organizing the R&D center reflect the nature of its work and its status with respect to production. The concentration on fundamental research, applied research, design engineering, or development determines the extent to which the center is organized as a scientific discipline or a responder to the needs of industry. This, in turn, determines the character of its staff and the complement of its internal subdivisions. For example, an Academy institute tends to contain a relatively homogeneous complement of natural scientists conducting "paper" research and drawing on laboratory services; an industry development organization tends to contain a relatively heterogeneous complement of engineers and technicians conducting design, small-scale manufacture, and testing work and drawing on experimental and pilot production facilities. Many organizations, of course, encompass more than one stage of the R&D process.

The relationship of the facility to production determines the legal status of the facility. It may be independent, with a technically oriented management and maintaining a full complement of supply, sales, and other functional departments to service its requirements; or it may be formally incorporated with production facilities. The internal status of the R&D center is important because it determines largely the degree of autonomy of the research function and the relative priority of R&D vis-a-vis production. If the R&D unit lacks legal and administrative independence, it frequently is reduced to providing first aid to industry. In Siberia, for example, only eight percent of the research and engineering personnel of

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R&D subdivisions at industrial establishments in the early 1970s actually conducted scientific R&D. The remainder were engaged in servicing the needs of production or in making minor improvements in the technological base.[12]

In the new associational forms linking research with production, the status of the R&D center varies. In a science-production association (NPO), a research institute or design bureau is ordinarily the lead organization, while in a production association a research institute, design bureau, or general R&D department is generally subordinate to production management. In these new complexes and integrated structures, management must be concerned, in varying degrees, with both production and R&D, and functional departments typically service performers of both activities. Because these organizations are heavily concerned with the application of results in production and use, we consider them further in that context later in this chapter.

Recently, Soviets have become more interested in the organizational problems of R&D and production facilities. The drive to create an optimal system of interrelationships between individuals and groups is termed "scientific organization of labor," and it may be recalled that a section of the S&T plan is devoted to this subject. For the most part, this concern devolves into "time and motion" studies and analyses of material flows on the shop floor, but there is also mounting concern with organizational structure and the management process. The Soviet regime has long formulated standard organization tables for establishments by function and by size of labor force. However, these have generally not been scientifically substantiated and have been characterized by extreme specialization of functions with emphasis on vertical lines of command. The lack of organizational flexibility has indeed been one important obstacle to innovation.[13] Scientific work has been organized like industrial activity. Little attention was given to the optimal size and structure of personnel and operations. As a rule, leaders of R&D units have demanded automatic increases in the number of scientific workers and support staff. Only recently have they become aware that expanding the size of the work force may actually lead to a decline in productivity, to a lengthening of the decision process, and to increases in cost.[14] There has been a universal depreciation of organizational and managerial factors in research, development, and innovation in the USSR. "Paradoxical as it may seem," a group of science analysts in Novosibirsk observed in 1971, "in our country science is probably the only sphere of human activity for which economists, planners, supply personnel, etc. are not specially trained. For all these persons there are not even special courses to retrain them for working in scientific institutions or to improve their qualifications."[15]

Finally, the spatial distribution of R&D establishments is an issue. This decision has generally been left to middle management organs, such as the Academy presidium and ministry collegia. Important considerations included historical precedent (e.g., an initial R&D base dating from the Tsarist era), proximity to ministry main administrations, proximity to educational facilities, proximity to the industrial facilities of the ministry, and the general amenities of the locale. As a consequence, Leningrad and Moscow became science centers, but the benefits of geographic colocation between facilities of several hierarchies were realized only when the decisions of their independent management bodies happened to coincide. Recently, however, the Soviets have come to appreciate the value of the

> 'research complex' as an innovation-promoting organizational device. A research complex is a cluster of research institutes specialized in different fields and working closely with neighboring enterprises. The variety of specializations facilitates the interdisciplinary cooperation often required in applied work, and the close association with neighboring industrial enterprises makes for greater ease in prototype construction, testing, and innovation.

> The most ambitious research complex is the one that has grown up in the Academic City of Novosibirsk, which is taking on some of the characteristics of the research-based industrial clusters around Boston, Palo Alto, and Houston.[16]

The Academic City at Novosibirsk incorporates predominantly Academy facilities of different departments, some of which have developed close ties with branch design bureaus and pilot plant facilities. Science-production centers are also planned to be built around institutes of the Lithuanian Academy of Sciences in chemistry, chemical technology, and the physics of semi-conductors. Similarly, in Kurgan the recent formation and expansion of facilities of four ministries concerned with ground vehicles, including automotive, agricultural, railroad, and construction equipment, reflect this enhanced belief in industrial "cross fertilization." Bureaucratic barriers, rooted in and reinforced by the organizational and spatial separation of R&D performers, are increasingly recognized as harmful.

The structure of the Soviet R&D establishment is thus influenced first by the nature of the activity in question. Beyond this, organizational structures tend to permit little flexibility compared to Western standards. Extreme specialization of activity and vertical lines of command are the norm. Basically, the research-to-production cycle has been broken up in time, task, and territory. Recent developments of particular interest are the closer organizational ties between research and production in the "association" unit and the development of research complexes characterized by geographic collocation.

CONDUCT OF R&D

Execution of R&D plans depends on acceptable criteria of fulfillment. While production targets may be measured by tons, units, rubles, or other physical and value indicators, there is no entirely satisfactory measure of research or innovative output. This is particularly true at the stages of fundamental and applied research. For many years the measure of inputs has been by default simultaneously the measure of output.[17] In other words, if budgeted expenditures in fact were spent, then the plan was considered fulfilled. The number of projects has also been used as a criterion, but this raises problems of project definition, determination of completion, and noncomparability between projects. With narrowly applied research, design, and development efforts have been made to measure success in terms of technical coefficients or the ultimate economic benefit of R&D results. These efforts are hampered by imprecise statistics and conceptual measurement problems.

Like their American colleagues, Soviet authorities have yet to resolve this problem if, indeed, resolution is possible. The criterion of project completion seems generally to predominate, although not much reliance is placed on it, especially in the production establishment, where fulfillment of technical plans generally is not a primary establishment success indicator, although informal evaluation of technical performance is an important determinant of managerial career paths. By whatever criterion employed, plans relating to science and technology more often than not have not been entirely fulfilled, with percentage completion figures often ranging from 50 to 90 percent.

Direct Control Mechanisms

Plan fulfillment is controlled in general in the same way as plan formulation. Specifically, organs responsible for administrative supervision of establishments monitor fulfillment of the entire establishment plan, while other management bodies monitor fulfillment of important aspects or specific functional areas of plans. For example, in line relationships the enterprise plan is monitored by the ministry, and the ministry plan by Gosplan on behalf of the Council of Ministers. State committees, in turn, monitor execution of important tasks (e.g., the GKNT) or a functional area of the establishment plan, such as supply (Gossnab). In addition, Gosbank has an important role in overseeing the financial flows which are planned to correspond to physical flows, and the CPSU exercises a general oversight function.

Within the performing establishment, program control techniques incorporated in various plans facilitate conduct of the R&D project. We noted, for example, that thematic plans of research institutes and design bureaus are based on "calendar plans;" formulated on a project basis, these subdivide the work into stages, designate responsible individuals, and schedule completion dates. Recently, a more formal research management technique has been developed: "network planning and control." In broad terms, a network model is any construct which is "dynamic, informational, and reflective of the process of performing a complex of tasks directed to the achievement of a single goal."[18] In practice, this can mean little more than such tools as grid schedules and Gantt charts for diagramming activities in sequence and for monitoring time, cost, and quality parameters. However, it also includes Soviet development and application in the early 1960s of more sophisticated techniques which resemble PERT and critical path methods.[19]

In the mid-1970s, network methods are said to have gotten their "second wind," according to Dr. Yu. I. Maksimov. Three factors have stimulated this recent growth: (1) the introduction of management information systems that provide the necessary information, norms, and technology for their application; (2) increased utilization of multistage econometric models linking the stages of planning, design, and production; and (3) the development of analytical aids and computer programs for calculating and optimizing not only specific network charts but also alternative stochastic network models. Examples of more sophisticated network techniques along the lines of CPM and PERT that surfaced in the 1970s for complex interbranch projects are the so-called "Sputnik" and "Skalar" systems. In addition to evaluating time and cost elements, network methods are also improving handling of materials and technical supplies and allocating manpower in R&D organizations. On the whole, however, their application remains limited; they are still largely confined to the major scientific centers, notably Moscow, Leningrad, Kiev, and Novosibirsk, and to major large-scale projects.[20] Such planning and control techniques, it may be noted, are compatible with the Soviet predilection for structured, planned activities. Their development and application to date have been constrained, in large part, by structural factors and the organizational-managerial fragmentation of the innovation cycle.

Other features of program control in the Soviet performer establishment center on the creation of the optimal internal organizational structure for support of R&D. As previously indicated, much interest has been expressed in the development of "organic" links between R&D and production, the topic of the next section. But even within the independent R&D establishment, Soviet authorities have found it advantageous to associate and link R&D personnel responsible for distinct stages or aspects of a complex project. Two pertinent dimensions may be identified: association between individuals working on separate stages of product or process development, and association between individuals working at the same stage of, respectively, product and process development. The benefits of such close contacts are said to have been instrumental in developing the ceramic tile manufacturing process.[21] Accordingly, numerous research institutes and design bureaus are expanding direct forms of cooperation and collaboration among the various participants in the research-to-production cycle.

In addition, some performer establishments have begun to experiment with forms of project management and matrix organization to break down intrainstitutional barriers, departmental and functional, and to accelerate the innovation process. A discussion of the pressures generating the conversion to matrix management is found in chapter 12. The deficiencies and limitations of traditional hierarchical forms of administration are thus being increasingly felt, and efforts are underway to develop new and more dynamic structural designs to cope with the problems of advancing technology and complexity.

As regards methods of conflict resolution the experience of modernizing production operations at ZIL is instructive. Whenever delays or deviations in program development arose, a meeting was convened of representatives from ZIL, organizations participating in the project, local organs, and pertinent ministries. Problems were settled through joint agreements of the interested parties with the formulation of the appropriate protocol. Any conflicts between organizations subordinate to the Ministry of the Automobile Industry which they could not settle themselves were resolved by the leadership of the ministry. The solution was binding for both sides. If disagreements arose between organizations of different ministries, the matter was examined by the appropriate ministerial authorities. Sometimes a joint decision by the interested ministries resolved the issue. Disagreements over questions of planning were examined by Gosplan, supply problems were handled by Gossnab, and S&T problems were mediated by the GKNT.[22]

The formality and rigidity of these procedures to resolve conflict prevent rapid application of corrective measures. Such procedures also breed conservatism in the performer at the time of plan formulation and, in a sense, frustrate central control by insulating the performer with layers of paper and delays.[23]

Conflicts are inevitable in any project. Coordination is the process of managing conflict. Conflict management practices keep different units together as they work toward integrated goals. In the Soviet Union organizational separation and administrative fragmentation of the innovation process complicate greatly the task of coordination and necessitate cumbersome mechanisms for settling disputes and forcing decisions. The considerable time spent in negotiation and getting approvals indicates, in fact, a lack of effective coordinating bodies and conflict-resolving practices, especially at the interfaces of agencies where management is critical to assure continuous action.

Indirect Control Mechanisms and Incentive Systems

In addition to direct, administrative control mechanisms, Soviet authorities are beginning to apply indirect techniques to structure the environment and influence the decision rules of the performer establishment so that the manager or researcher supports innovation. Many of these mechanisms are in fact formal inactive programs while others concern programs which facilitate supply, sales, technology transfer, and other activities, all of which increase managerial flexibility and effectiveness. In this part, we briefly comment on several indirect mechanisms of particular importance in R&D program control. Mechanisms which predominantly concern the production establishment are left until the discussion of utiliization of results, even though they may impact on the conduct of R&D in such organizations.

An adequate supply of personnel, material inputs, and capital equipment is of course a prerequisite for any R&D program. The Ministry of Higher and Specialized Secondary Education forecasts future labor requirements (by profession and skill) of science and of the economy in concert with Gosplan, the GKNT, and the Academy of Sciences. In accord with planned manpower needs, students are induced to follow certain career paths with stipends and the standard attractions of employment following graduation. Given the tremendous expansion in the number of scientists and engineers over the past two decades, the quantity and quality of S&T personnel have generally not slowed down R&D. While salary ranges are fixed for certain categories of employees, R&D facilities effectively bid for workers in a manner similar to competition for labor in the United States. Appropriate allocation of personnel, then, generally is assured, with one major exception. Maximum salary levels are fixed in relation to the nature of the organization at which the scientist or engineer is employed. Accordingly, the best S&T personnel have tended to gravitate away from industry to the Academy system, and within industry from production to R&D establishments. This doubtless has hindered industrial R&D and associated production assimilation, although in recent years the relative position of industry seems to have improved somewhat.

At the same time, certain deficiencies of the system of planning and training scientific manpower merit brief mention. Surpluses of specialists exist in some, more traditional fields of science and technology and shortages in other areas, such as computers, biochemistry, and microelectronics--the main pacesetters of modern S&T progress. Experts in the modern social sciences and management sciences are also lacking. The orientation of planning and professional training has not kept pace with changes in science, technology, and organization. "Existing programs of education are not designed to train specialists in the subjects needed by modern society and by research, planning, and design organizations," observes Gvishiani.[24] The acceleration of technical progress also makes obsolete information, knowledge, and acquired skills, so that the retraining of scientific, engineering, and managerial personnel is becoming increasingly necessary. This need is all the more pressing in view of the mounting constraints on manpower resources which require greater attention to qualitative improvements rather to quantitative increases in the size of the S&T establishment.

Acquisition of material supplies, another control mechanism, generally is planned at the same time that basic R&D and production assignments are formulated. Gossnab is the principal agency in charge of planning and distribution of supply. The Soviet material and technical supply system is conducive to large-scale deliveries of fairly standardized products, but not to the typical small-lot deliveries of special purpose items required for R&D. Only recently have special science supply organizations been set up, but these still operate only on a small-scale, limited basis. As already indicated, many deficiencies exist in the supply system which add uncertainty and risk to all innovation efforts. Finally, access to supplies of capital equipment for experimental purposes is handled either by Gossnab, for small-scale acquisitions, or by Gosstroy when new construction or major reconstruction of facilities is needed. Traditionally, Soviet authorities have chosen to minimize investment in an experimental base and scientific instruments industry in favor of investment in on-line production facilities. While an extensive campaign is now underway to correct deficiencies in experimental and pilot plant establishments, the Soviet pattern in certain sectors is still deficient by Western standards.

The Soviet patent system also affects R&D. Soviet policy concerning inventions and discoveries and associated patents and author's certificates is administered by the State Committee for Inventions and Discoveries in concert with legal authorities. Patent departments now generally exist in ministries, research institutes, and production organizations to service the inventor.

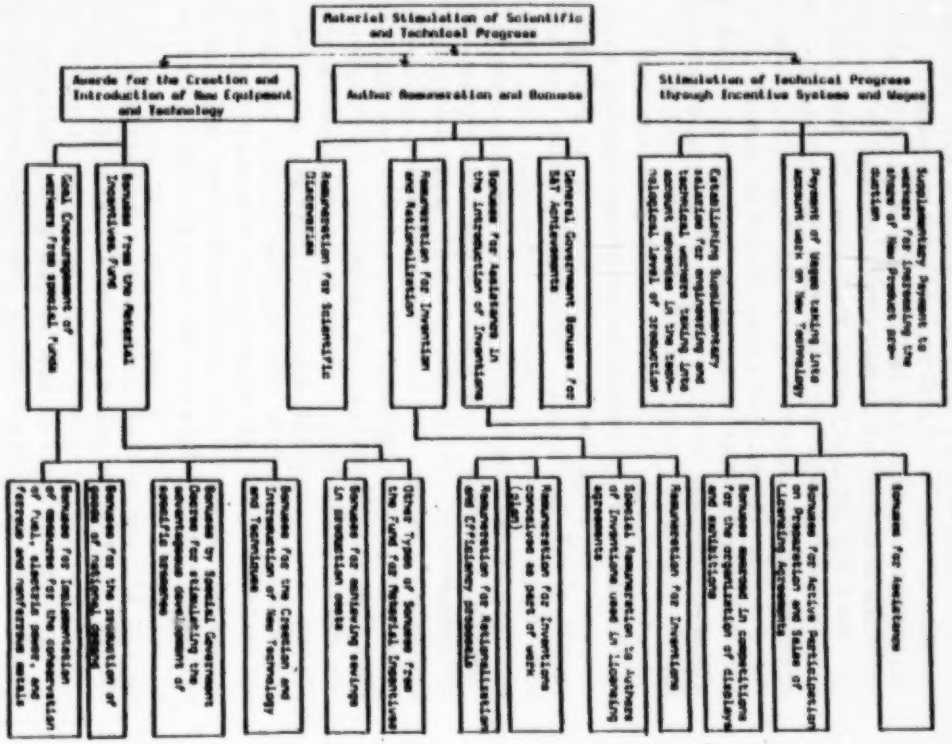
In contrast to the American system, proprietary rights over inventions in the USSR are held by the state. Rather than permit the inventor to retain a monopoly use of the invention for a designated period and thus retard diffusion, the Soviets have chosen to compensate the inventor with a lump sum payment. Remuneration is paid if the invention is used not only in the USSR but also abroad in the sale of licenses, in documentation transmitted to other countries by way of economic and S&T collaboration, or in installations built by the USSR abroad as part of its foreign technical assistance programs. The maximum award for a single invention cannot exceed 20,000 rubles, however. Discoveries are also rewarded with a one-time payment in the amount of 5000 rubles. Cash awards are also given for rationalization proposals which result in efficiency improvements, and may vary from 10 rubles to 5000 rubles.[25]

This discussion of inventions and associated compensation serves as an introduction to the Soviet incentive system, perhaps the most important of all the indirect control mechanisms. It is certainly one of the most complex. Figure 11-1 illustrates those elements of the system concerned only with material incentives, in both the independent R&D organization and the production establishment. Incentives are channeled through wage manipulation and bonus funds; of the latter there are general funds of the organization and funds associated with special activities. There are also collective and individual bonuses. Throughout all these programs, however, the economic theme predominates; whenever possible, remunerations are predicated on the economic savings produced by the contributions.[26]

At independent R&D organizations, incentives tend to be associated more frequently with the activities of individual scientists or groups of scientists rather than the overall results of the organization. Certainly this approach derives from the tendency of researchers to be project-oriented and from the difficulty of evaluating aggregate performance of the institute or design bureau. Material incentive programs which benefit personnel at independent R&D establishments include prizes for especially noteworthy scientific research and development. At the national level these are Lenin and State Prizes. These prizes are awarded annually for the most outstanding achievements. State prizes are also awarded in science and technology by the republics of the USSR. In recent years the Central Committee of the All-Union Young Communist League has given "Young Komsomol Prizes" to young scientists for especially outstanding S&T accomplishments.

In addition, creators of the best displays at the Exhibition of Achievements of the National Economy are presented gold, silver, and bronze medals and certificates each year. For areas of technology warranting special attention, a highly flexible system

FIGURE 10-1 THE SYSTEM OF MATERIAL STIMULATION OF SCIENTIFIC AND TECHNICAL PROGRESS IN THE USSR


Material Stimulation of Scientific and Technical Progress
Awards for the Creation and Introduction of New Equipment and Technology
Author Remuneration and Bonuses
Stimulation of Technical Progress through Incentive Systems and Wages
Goal Encouragement of workers from special funds
Bonuses from the Material Incentives Fund
Remuneration for Scientific Discoveries
Remuneration for Invention and Rationalization
Bonuses for Assistance in the Introduction of Inventions
General Government Bonuses for S&T Achievements
Establishing Supplementary salaries for engineering and technical workers taking into account advances in the technological level of production
Payment of Wages taking into account work on New Technology
Supplementary Payment to workers for increasing the share of New Product production
Bonuses for Implementation of measures for the conservation of fuel, electric power, and ferrous and nonferrous metals
Bonuses for the production of goods of national demand
Bonuses by Special Government Decree for stimulating the advantageous development of specific branches
Bonuses for the Creation and Introduction of New Technology and Techniques
Bonuses for achieving savings in production costs
Other Types of Bonuses from the Fund for Material Incentives
Remuneration for Rationalization and Efficiency proposals
Remuneration for Inventions conceived as part of work (plan)
Special Remuneration to Authors of Inventions used in licensing agreements
Remuneration for Inventions
Bonuses awarded in competitions for the organization of displays and exhibitions
Bonuses for Active Participation on Preparation and Sales of Licensing Agreements
Bonuses for Assistance

Source: P. S. Miroshnikov, A. F. Kotlyarov, and V. P. Babich, Materialnoye stimulirovaniye nauchno-tekhnicheskogo progressa (Kiev, 1973), p. 64.

of special awards has been set up. Thus, 100 bonuses have been established for the solution of the most important problems in chemistry (25,000 to 150,000 rubles); 15 bonuses for putting into production new models of tractors, agricultural and land reclamation machines, etc.[27] Finally, in each independent R&D organization, a bonus fund is provided for the "successful solution of scientific problems." The size of the fund is equal to 2-3 percent of the establishment's total wage fund, and is allotted by the management of the establishment for high quality work, for projects completed on or ahead of schedule, and for R&D results that find practical application. Management also may tie a portion of the fund to especially important projects.[28]

While monetary incentive programs are important economic levers, Soviet authorities also put considerable stock in "moral" incentives, which include a wide range of prizes, awards, commendations, medals, and special titles. Of course, several material incentive programs, particularly the prizes, carry with them important public and professional recognition and commendation. Individuals who are actively engaged in S&T developments are awarded honorary titles, such as "meritorious inventor" and "meritorious efficiency expert," and they are given some privileges in getting apartments, vacations and travel, etc. Individuals who distinguish themselves in some special way earn the prestigious title of "Hero of Socialist Labor." S&T achievements may also be prerequisites for promotion of specialists and bestowing of scientific degrees and titles. It is equally apparent that moral incentives have an indirect, although possibly belated, material incentive content.

Each of these elements of the incentive programs for R&D personnel is more or less independent of the ultimate application or use of R&D results. Introduction or utilization of results is stipulated as an important reason for bonuses under each of the incentive mechanisms, but it is generally not an absolute requirement.

Finally, there is one incentive program that merits special mention because it aims at stimulating the interests of researchers, design engineers, and producers alike in the entire research-to-production cycle, in the economic aplication of R&D, and in the reliability and performance of new technology. The source of this program is the Fund for the Creation and Introduction of New Technology. At industrial plants, this fund is generated through deductions from the cost of production amounting to 0.2 to 1 percent of the wage funds of industrial production personnel. At research institutes and design bureaus these funds are specially provided for in their budgets and range from 4 to 10 percent of the annual wage fund. Enterprises retain 25 to 50 percent and R&D facilities retain up to 50 percent of these funds and divert the rest into centralized incentive funds at their respective ministries which are used to reward work on especially massive and important projects.[29]

The size of bonus awards depends on the annual economic savings due to technological innovation and is determined on the basis of the scale presented in Table 11-1. Staff members of research institutes and design bureaus can claim 30 to 50 percent of the bonus, technology developers 20 to 35 percent, and production workers 25 to 40 percent. Ninety percent of the incentive funds should be used to reward those who directly participate in the work and 10 percent should go to those who assist in innovation and utilization. For completion of projects ahead of time, the size of the bonus is increased by 25 percent.[30]

Interesting features of this system are (1) the association of rewards with results regardless of the organizational affiliation of the participants, (2) the flexibility intended by the centralization of a large share of the fund, (3) the rigid and somewhat arbitrary character of the shares of bonuses as a function of the stage of R&D, and (4) the reliance on the ubiquitous measure of "economic return." The unreliability of this measure, the decline in the bonus share with rising benefits, and misapplication of

TABLE 10-1

THE STRUCTURE OF BONUS AWARDS FOR TECHOLOGICAL INNOVATION IN THE USSR

Annual Economic Return of the Innovation (thousand rubles)	Amount of Bonus as Percentage of the Annual Economic Return
Up to 10	6 to 25%, but not over 2000 rubles
10 to 20	5 to 20%, but not over 3400 rubles
20 to 50	4 to 17%, but not over 6000 rubles
50 to 100	3 to 12%, but not over 10,000 rubles
100 to 500	2 to 10%, but not over 35,000 rubles
500 to 2000	1 to 7%, but not over 80,000 rubles
2000 to 5000	0.7 to 4%, but not over 150,000 rubles
above 5000	0.5 to 3%, but not over 200,000 rubles

Source: I. D. Ivanov, "Overcoming Obstacles and Stimululation During the Introduction of New Technology and New Management Methods (Russian text)," p. 11.

funds have diminished the effectiveness of this program. Yet there is potential in this and other programs to redirect the attention of scientists and engineers to economic application, which is perhaps the major theme of all current developments in Soviet program management and control mechanisms regulating the conduct of R&D.

UTILIZATION OF R&D RESULTS

The growing Soviet concern, reflected throughout this study, for effective application of R&D results in production and use is a consequence of two trends: (1) the rising dependence of continuing Soviet economic growth on technological innovation; and (2) relatively poor Soviet performance in translating scientific ideas into new products and processes. The first necessitates improved performance in the entire R&D sector. The second focuses on the greatest problem within that sector. As General Secretary Brezhnev phrased the issue in 1971, "If one examines all the links of the complex chain uniting science with production, it is not too difficult to see that the links connected with the practical realization of scientific achievements and their adoption in mass production are the weakest."[31]

The overriding reason for this deficiency is the absence, under traditional Soviet operating practices, of individuals and organizations that are both capable of and interested in effecting the transition to application. In principle, the independent research, design, and development organizations are obligated to supply the production establishment with technical documentation, working blueprints, and/or prototypes of new products and processes ostensibly ready for utilization. But the effective judge of the "readiness" of an innovation is the designer or developer himself, and he has little incentive to undertake gratuitously activities which will only help the producer. The latter, in turn, receives little or no credit for doing design or development work that should already have been completed satisfactorily, and he recognizes that demonstrating culpability is most difficult. Innovation to the factory is almost always a nuisance. It frequently involves substantial redevelopment, if not wholesale scrapping of received results and starting anew. In various sectors of machine building more than half of the plan tasks for the assimilation of new technology are incomplete due to deficiencies and errors at the research, development, and design stages.[32]

To facilitate the transition, Soviet authorities have recently taken several reform measures. These may be grouped into plan-related, organizational, and financial measures.

Plan-Related Developments

The fundamental means of accounting for introduction of R&D results, as we have seen, is specification of all pertinent variables in the plan of the R&D organization. Scheduled completion dates and expected manufacturing establishments are required, in principle, to be designated in R&D project plans. Difficulties in making these assignments effective, however, include the problem of forecasting results accurately at the initiation of R&D work and of eliciting the cooperation of the manufacturing enterprise. In addition, it is unclear whether the manufacturer subsequently is obligated to accept the innovation, and the nonbinding character of many R&D plan tasks combined with the difficulty of determining culpability tend to vitiate the potency of plan stipulation. Most important, however, mere stipulation does little to alleviate the underlying causes contributing to reluctance to innovate. And Soviet managers have proven to be adept at modifying plans "from below" and frustrating the real intent of central authorities when their interests are threatened.

Other plan-related developments involve an extension of the systems approach to include the utilization stage. This may involve little more than developing network models and grid schedules to include steps related to application, but even this extension can force consideration of the entire research-to-production cycle as an integral unit. With clear delineation of responsibility, culpability for failure is easier to fix. Network approaches also require careful scheduling and provide a framework for accommodating unanticipated developments. All of these elements reduce project uncertainty and risk and benefit considerably the production establishment, which must function in an environment hostile to "slack" and uncertainty.

An interesting policy development is the creation of standard "systems" for regulating activities. The State Committee for Standards is responsible for developing methodologies for technical norms, standards, and quality certification programs, and for overseeing application of such methodologies. Such functions are of course essential in any industrial economy, but particularly so in the Soviet Union where the absence of an effective market mechanism means that the state must ensure that common design, development, and production practices are utilized where such commonality is advantageous. This is particularly useful in avoiding unnecessary duplication of effort in design.

In recent years, Gosstandart has developed certain families of procedures to ensure that standards formulated in a decentralized manner will be comparable and transferable throughout the economy. The first such system was the Unified System of Design Documentation (YESKO), intended to unify design approaches. Other unified systems since developed include those for standardizing data processing techniques (YESSTEM), classification and coding (YESKK), computer languages (YESPD), and procedures for evaluating product quality (YESKAP). The most ambitious system is the Unified System for Technological Preparation for Production (YESTPP), directly aimed at the problem of introducing R&D results. It incorporates elements of the other special systems and in total contains 3500 state standards on all phases of the preparation of new products and processes, including design, devel-

FIGURE 10-2 EXEMPLARY PLANNING CHART FOR TECHNOLOGICAL PREPARATION FOR PRODUCTION IN THE USSR MINISTRY OF THE AUTOMOBILE INDUSTRY

No. by Order	Designation of Fundamental Stages and Operations	Performing Organization	Duration According to Plan, Actual Execution											
			19 x 1				19 x 2				19 x 3			
			I	II	III	IV	I	II	III	IV	I	II	III	IV
	A. Design Preparation	Department of the Chief Engineer (OGK) Experimental Shop (ETS)												
1.	Project-design work (Development of documentation)	Design Bureau (KB); OGK	—	—	—	—								
2.	Preparation of experimental models	ETS; OGK			—	—								
3.	Testing of experimental models	ETS; Laboratories of the OGK				—	—	—	—	—				
4.	Refining of designs in experimental production	ETS; Laboratories of the OGK							—	—				
	B. Technological Preparation	Chief Technologist; Chief Metallurgist												

FIGURE 10-2 (continued)

No. by Order	Designation of Fundamental Stages and Operations	Performing Organization	Duration According to Plan, Actual Execution											
			19 x 1				19 x 2				19 x 3			
			I	II	III	IV	I	II	III	IV	I	II	III	IV
1.	Technological analysis of drawings, development of paths for production of parts in shops	Technological Services					—							
	Allocation of assignments to shops, departments	OPP of the Technical Department												
2.	Development of technological processes; formulation of tasks for design of machinery, tools, equipment and other means of production	Technical Unit of Technological Department; Technological Bureau of Shop Production					—	—	—					
3.	Designing means of tooling production processes	Design Bureau of the departments of designing production equipment							—	—	—			
4.	Preparation of machinery, equipment, tools	Tool Production								—	—	—	—	

FIGURE 10-2 (continued)

No. by Order	Designation of Fundamental Stages and Operations	Performing Organizations	Duration According to Plan, Actual Execution											
			19 x 1				19 x 2				19 x 3			
			I	II	III	IV	I	II	III	IV	I	II	III	IV
5.	Production, installation, and start-up of equipment	Department of equipment, mechanic												
6.	Organization of work sites, adjustment and assimilation of processes	Project-installation service												
7.	Production of trial batch of articles by basic processes	Production shops, production-dispatch department												

Source: B. Ye. Yusufovich and P. V. Fedortsov, "Improving the Organization of Planning of Technological Preparation for Production in the Automobile Industry," Avtomobilnaya promyshlennost, 4 (1973): 3.

opment engineering, testing, and introduction as well as the associated process, equipment, and tooling requirements.

An example of the YESTPP system as envisioned for the automobile industry is depicted in Figure 11-2. Subsumed under each activity are instructions regulating its conduct. As may be seen, the system is particularly advantageous in permitting parallel work on separate design and development stages. This is especially important in the mass production of a complex product where the development of process technology may be extensive and time consuming. Numerous Soviet statements indicate that YESTPP and other systems approaches have reduced significantly the lead time required for innovation.

In general, these efforts seek to alter the traditional perspectives and motivational bases of Soviet design engineers and developers of new technology. Designers have tended to use heavy metals and reinforced concrete articles that are expensive because they are profitable for those creating new devices and erecting new installations since they are evaluated in terms of the cost of structures and models. In addition, designers of new technology are also paid more if their blueprints are "original" and require nonstandard equipment. Thus, it has not been advantageous for design organizations to include in their drawings and models standard parts and components for this reduces the cost of designs and subsequently their bonuses. It is these practices and procedures that account for the great volume of unique and small batch production in the USSR, especially in machine-building and instrument-making.[33]

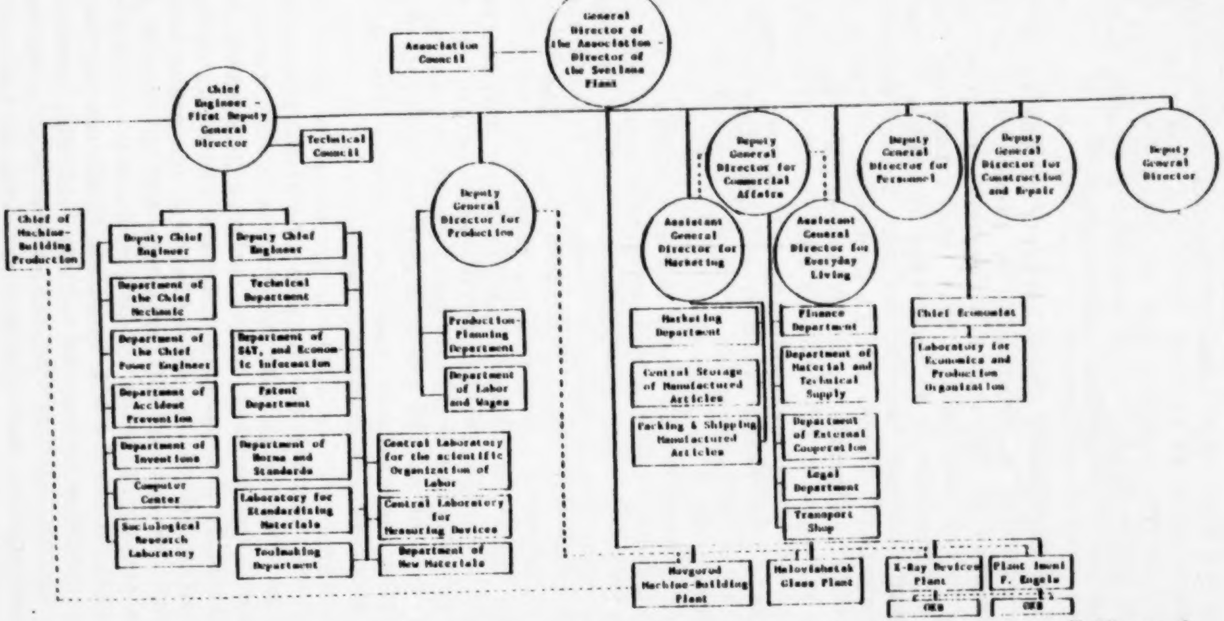
Organizational Developments

Organizational measures designed to facilitate the implementation of R&D results include manipulation of the internal make-up of the basic operating units and the creation of entirely new types of organizations. These measures are premised on the plausible belief that applied R&D personnel and facilities will better serve the interests of production if they are brought into closer association with, if not formally incorporated into, establishments for which production is a primary mission.

In this context, we discuss production associations (POs) and science-production associations (NPOs). These new complexes represent an attempt to build unified organizational systems rather than unrelated or disjointed arrays of tasks, functions, and individual efforts. Such integrated structures are designed to give institutional expression and coherence to the innovation process. Some science policy experts in Moscow argue, in fact, that only through research and development complexes can the "research to production" cycle be effectively carried out from beginning to end.[34] The move to create special organizations concerned with applications engineering and diffusion is less well advanced, and only brief attention is given to them.

As noted previously, the Soviet enterprise typically corresponds to a single-plant Western company with extremely limited design, development, and experimental capabilities. The production association, combining formerly independent R&D and production units, is fast becoming the basic economic organization of Soviet industry. A major aim of establishing POs is to insure that series or mass production of the most advanced items is set up for the internal market and for export. The POs are comprised of technologically integrated production enterprises with research institutes and design bureaus attached to them. For example, the Leningrad instrument manufacturing production association Svetlana has experimental research and design divisions that work closely with its production facilities in developing new hardware models, a special design bureau for creating technological equipment for their industrial testing, and shops for manufacturing this equipment. The organizational structure of this association is depicted in Figure 11-3. Note the experimental design bureaus (OKBs) which are subordinate to two of the association's plants. The presence of a comprehensive experimental research facility is characteristic of POs especially in machine building, and the metallurgical,

FIGURE 10-3 ORGANIZATIONAL STRUCTURE OF THE SVETLANA PRODUCTION ASSOCIATION


Association Council
General Director of the Association - Director of the Svetlana Plant
Chief Engineer - First Deputy General Director
Technical Council
Chief of Machine-Building Production
Deputy Chief Engineer
Department of the Chief Mechanic
Department of the Chief Power Engineer
Department of Accident Prevention
Department of Inventions
Computer Center
Sociological Research Laboratory
Deputy Chief Engineer
Technical Department
Department of S&T, and Economic Information
Patent Department
Department of Norms and Standards
Laboratory for Standardizing Materials
Toolmaking Department
Central Laboratory for the scientific Organization of Labor
Central Laboratory for Measuring Devices
Department of New Materials
Deputy General Director for Production
Production-Planning Department
Department of Labor and Wages
Deputy General Director for Commercial Affairs
Assistant General Director for Marketing
Marketing Department
Central Storage of Manufactured Articles
Packing & Shipping Manufactured Articles
Assistant General Director for Everyday Living
Finance Department
Department of Material and Technical Supply
Department of External Cooperation
Legal Department
Transport Shop
Deputy General Director for Personnel
Deputy General Director for Construction and Repair
Chief Economist
Laboratory for Economics and Production Organization
Deputy General Director
Novgorod Machine-Building Plant
Malovishetsk Glass Plant
X-Ray Devices Plant
Plant imeni F. Engels
OKB
OKB

Source: A. Domachev and D. Shuzhentsov, "Leningrad Production Associations," Ekonomi- cheskaya gazeta, 5 (1970): 11-14.

chemical, and oil refining industries. A number of large POs even have research centers of all-union importance, such as the R&D service of the KAMAZ, and the scientific research and experimental design center of Elektrosila, which occupies a leading position in the world in turbine construction.[35]

A distinguishing characteristic of the PO is the clear emphasis on production at large-scale, efficient rates of output. A production facility, in fact, is the lead unit. Thus, while improved innovative performance is an important objective, other standard economic benefits of such larger units also are expected. These include economies of large scale production, specialization of subordinate units, and wider application of advanced managerial practices. The use of integrated planning techniques, computerized data processing systems, and organizational designs based on principles of purely project or matrix management has allegedly been instrumental in accelerating innovation in these new structures. According to Ivanov, the research-to-production cycle has been reduced for certain products by 50 to 75 percent in the Uralelektrotyazhmash Production Association. In the L'vov Instrument Manufacturing PO imeni V. I. Lenin this cycle was cut on an average by 50 percent, and the degree of interchangeability of assemblies was boosted to 80 percent while their weight was reduced by half and their reliability was raised by a factor of 3 or 4. In the Svetlana and Elektrosila production associations almost all development projects reach the production stage.[36]

The most significant organizational development, from "the long range view of scientific and technical progress," is the creation of science-production associations.[37] Set up in the late 1960s explicitly to organize innovation as a distinct and major task, NPOs function as special nurseries for the rapid generation and application of new technology. Though they exist in nearly all branches of industry, they are concentrated mainly in machine building, especially in the electrotechnical, electronics, instrument manufacture, and aviation sectors, as well as in the chemical and petrochemical industries.

Within industry, three basic types of NPO may be differentiated according to their final product: (1) those that specialize in developing primarily new products and technological equipment for their manufacture; (2) those that concentrate on creating new means of mechanization and automation of production, including management information systems; and (3) those that engage in the development of new materials and technological processes. The third type is less prevalent than the other two associations. A few NPOs, like *Mikrobioprom* (microbiological industry), *Soiuznauchplitprom* (wood processing), and *Plastpolimer* (chemical industry), engage simultaneously in developing new products, new processes, and new kinds of equipment and automated devices.[38]

NPOs differ also in terms of the scope of their specialization and product use. The majority are of branch importance. However, some NPOs like *Plastpolimer* are primarily subbranch while still others are essentially interbranch. The latter include *Soiuznauchplitprom* and *Soiuzsteklomash* (glass machine building), which develop articles used in construction, electronics, and defense as well as in the automobile, electrical engineering, instrument manufacture, light, food, chemical, and medical industries. Similarly, the All-Union NPO *Soiuztransprogress* was formed in 1974 to design, develop, and install transport container systems throughout the country.[39]

Numerous benefits are ascribed to these new integrated and integrating structures. The process of creating and applying new technology has been reduced in many NPOs by two and even three times.[40] The quality of research, development, and innovation is also higher. In the electrical engineering industry the share of output stamped with the seal of highest quality is 1.5 to 2.5 times greater in the NPOs than in the branch as a whole.[41] In the associations from 40 to 50 percent (and climbing to 80 and 90 percent) of completed R&D is actually introduced while in autonomous scientific and technological organizations only 15 percent is successfully utilized. Labor and material costs are also reduced because of less duplication, greater specialization, better organization of design work, fewer documentation errors, greater standardization of parts, and more extensive automation of work processes. In addition, NPOs are credited with harmonizing the actions, goals, and interests of different performers and with creating a more favorable climate for innovation. They enjoy greater possibilities of applying network planning methods and computer techniques to the innovation cycle, of using matrix organization and project management to improve the decision process and to build more dynamic and flexible structures. Above all, they are said to generate favorable conditions for the conduct of uniform policies and integrated leadership throughout the associations.[42]

As Berliner notes, however, much of the evidence on NPOs deals with the performance of individual or groups of associations. Aggregate data in systematic form are still lacking.[43] Nonetheless, there is sufficient fragmentary information and critical analysis to suggest a mixed record of performance and diverse development. Not all associations have been resounding successes. Even those NPOs that have been held up as stellar examples, like Pozitron and Plastpolimer, have important problems. Despite individual accomplishments and some remarkable gains, deficiencies persist in both the theory and practice of science-production associations.

One area of criticism and controversy concerns the optimal structure and composition of NPOs. Basically at issue are conflicting views about the essential purpose and function of the NPO. There is general consensus that in promoting the rapid creation and smooth transfer of technology the associations are to encompass the entire research-to-production cycle. The precise role and form of participation of the NPO in the initial and concluding phases of the cycle are debatable, however. There are two main schools of thought. One holds that the task of the association should be limited essentially to the development and testing of prototypes. According to this view, the business of series and mass production of new technology belongs not to the NPO but to the production associations and enterprises. If these two tasks are not delimited organizationally between science-production and production associations but are done within the NPO, then confusion and a distortion of functions takes place. The inclusion of enterprises engaged in series production leads to an expansion of manufacturing operations to the detriment of scientific R&D activity. The main function of the NPO--prototype development--becomes subordinate to the task of fulfilling current production programs.

Indeed the claims and fears of those adopting this view are confirmed by experience. In several NPOs the share of scientific research and experimental design comprises only 5 to 15 percent of the volume of industrial production activity. Some of these NPOs have, in fact, been subsequently renamed POs. In others, R&D results are accumulating and cannot find an outlet either at the association or at other enterprises of the branch. The share of new products originating in the NPO and assimilated into series production has also declined in recent years at Elektroapparat and Kondensator. More than half of the work of series production facilities at some NPOs deals with assignments that have nothing to do with the activities of their own R&D units and sometimes even fall outside the specialized profiles of the associations. NPOs having major enterprises of series and mass production have shown a strong tendency to become interested mainly in improving production indicators and not in accelerating innovation. To weaken the desire to maintain production runs of the same items and to encourage greater product mix and renewal, a new rule has recently been introduced. If an NPO issues a particular product more than three years, deductions to its incentive funds are then reduced by 50 percent.[44]

On the other hand, many specialists insist equally strongly that series or batch production is an integral part of the NPO. The role of series production facilities is not to increase industrial output but to serve as an arena within which the NPO can test and perfect its innovations under actual production conditions. If NPOs lack series production capability, this forces them to transfer the assimilation of new products and processes to other organizations. That prolongs the process and reduces the quality of innovation. In effect, the NPO is excluded from the most important stage connected with the introduction of R&D results into the economy and cannot perform its role of connecting link between science and industry. When the NPO concentrates mainly on "preproduction" work, it cannot really qualify as a "science-production" association.[45]

Views also differ concerning the place of the NPO at the research end of the innovation process. For that matter, there is no agreement in the Soviet Union about the place and role of basic research more generally in the research-to-production cycle.[46] Until recently, major NPOs like Pozitron themselves performed fundamental research equal to nearly 10 percent of their total scientific research effort. It became necessary to abandon this practice by the mid 1970s, however. While a few NPOs still engage in some exploratory research, the majority contract with institutes of the Academy of Sciences to conduct fundamental research for them.[47] Befitting their role and development as "branch" institutions, NPOs focus predominantly on applied R&D.

At the same time, the scope and volume of scientific research and development vary widely among NPOs. In some associations the share of R&D may be less than 10 percent of the total cost of production activity while in others it may account for as much as 50 percent.[48] Some Soviet specialists believe that a fixed percentage should be established for the ratio of "science" and "production" activity as a mandatory condition for the functioning of an NPO. Though he disagrees with this view, Taksir notes that when a complex is headed by a small research institute which conducts an insignificant volume of R&D (less than 10-12 percent), then the NPO is generally unable to direct effectively the research-to-production cycle. Arkhangelskiy also demonstrates that the capacity of the R&D center must be nearly 20 percent of the production capacity for an NPO to perform successfully its various functions.[49]

This aspect acquires special importance because the NPO is intended to serve as the S&T center for the branch or subbranch in its specialty. In fact, this is seen as a distinguishing feature of the NPO, differentiating it from a production association and other research and production complexes which may also contain R&D units. As branch S&T centers, NPOs are assigned several important tasks: long-range planning of the main directions of research; developing forecasts and programs to solve basic S&T problems in the branch, especially those related to improving production efficiency and product quality; and making recommendations about the use of R&D results in both the branch and the economy as a whole. NPOs are expected to coordinate scientific research, experimental design, and engineering work done by other organizations and production associations, regardless of the departmental subordination of these units. In addition, they perform other branchwide services, such as supplying S&T information, doing economic analysis and engineering feasibility studies, conducting work on patents and licensing, setting branchwide technical standards, forecasting the demand for new products and processes, and providing management training and advice on production organization with respect to new technology. The associations are also expected to develop and provide special services for introducing new technology, its assembly, start-up, and adjustment at other enterprises and organizations.[50] In providing these functions, the NPO clearly assumes (or shares) certain of the responsibilities formerly held by the ministry technical administration and other staff agencies.

To be sure, several NPOs do perform these tasks and act as the principal organizers of technical progress in their branches. *Soiuznauchplitprom* plays this role in the woodprocessing industry. One hundred and five enterprises of the USSR Ministry of Timber and Wood Processing Industry and 67 enterprises of other ministries produce items developed by the NPO. *Mikrobioprom* is the S&T headquarters for the microbiological industry. More than 70 enterprises work on projects originating at the association. *Plastpolimer* is the leading center for plastics and has overall responsibility for high pressure polyethelenes, polystyrenes, fluoro-plastics, and polyvinylacetates. Between 1969 and 1973 the NPO introduced 117 innovations into Soviet industry. In the cryogenic engineering industry nearly 90 percent of all machinery and equipment produced is based on designs developed at the industry's NPO *Kriogenmash*. In radio electronics *Pozitron* is the S&T center.[51]

At the same time, it is also clear that not all NPOs serve as S&T centers for their branches. Some associations serve only a few enterprises and contain very small R&D units. Others that do exercise branch-wide functions do not provide all the special services mentioned above. Some NPOs are unable to perform broad S&T tasks either because they lack a research institute or the one they have is not the leading link in the association.[52]

These basic differences in perception and practice determine the structure of science-production associations. Table 11-2 shows the structural makeup of 15 leading NPOs. All these associations contain both a scientific research institute and a series production unit. Thirteen have an experimental production capability. Other evidence suggests, however, a less uniform picture for the NPOs as a whole. In a study of 40 NPOs, Kushlin notes that 10 percent had no series production unit while 8 percent lacked a scientific research subdivision. Eighteen or 45 percent of the NPOs had no experimental production or testing facility.[53]

Particularly absent, it seems, are facilities such as start-up and adaptation organizations and training centers which can promote more rapidly and effectively the utilization of R&D results. A few NPOs, like *Pishchepromavtomatika* (food processing), *Soiuznauchplitprom*, and *Impuls* (computers), have established special services that help introduce new products and processes directly at client enterprises and train their personnel in the use and repair of equipment. At series plants of their branches other associations

TABLE 10-2

STRUCTURAL MAKEUP OF SCIENCE-PRODUCTION ASSOCIATIONS

Name of the NPO	Subdivisions included in the Association							
	Scientific Research Institute	Design Bureau	Design-Technological Bureau	Project Organization	Experimental Production Plant	Series Production Facility	Assembly, Startup and Installation Organization	A Training and Methods Center
Agropribor	+	-	+	+	+	+	-	-
Soiuznauchplitprom	+	-	+	+	+	+	+	-
Sakhar	+	+	-	-	+	+	-	-
Sistema	+	-	+	+	+	+	-	-
Istochnik	+	-	-	+	+	+	-	-
Mikrobioprom	+	-	-	+	+	+	-	-
Soiuzsteklomash	+	-	+	+	+	+	-	-
Znamia Truda*	-	+	-	-	+	+	-	-
Plastpolimer	+	+	-	+	+	+	-	-
Burmash	+	-	-	-	+	+	-	-
Positron	+	+	+	-	+	+	-	-
Pishchepromavtomatika	+	+	-	+	+	+	+	+
Ritm	+	-	-	-	-	+	-	-
Soiuzavtomatstrom	+	-	-	-	-	+	+	-
Turan	+	-	-	-	+	+	-	-

* The head unit of the NPO is the Central Design Bureau for Construction Engineering which is essena scientific research institute

Source: K. I. Taksir, *Nauchno-proizvodstvennyye obedineniya* (Moscow, 1977), p. 34.

have created special departments (affiliate services of the NPO) which include design engineers and technologists who assist the plants in retooling and manufacturing new products.[54] In general, though, this set of important functions is not yet being performed by the majority of NPOs.

Underlying these issues of the optimal structure, composition, and functions of the science-production association is the problem of what in American business terminology is called "product differentiation." Given the array of new structural designs and associational forms that have evolved since the late 1960s, the NPO has had difficulty in gaining and maintaining a distinct identity. Lacking a precise definition of the NPO, some ministries have arbitrarily classified the new complexes. What are labeled NPOs are, in fact, production associations or complex scientific institutions. Some NPOs have experienced problems in preserving their fundamental dual character. Overdevelopment of their scientific functions turns the NPO into a traditional research institute, only larger. Hypertrophy of production operations, on the other hand, transforms the complex into a production association. The difficulties of maintaining a "dialectical unity" of functions have led some experts to press for a fixed ratio or at least minimum levels regulating these activities.[55]

The problem of product differentiation is made all the more difficult because in some instances it is practically impossible to distinguish between an NPO and a PO which contains its own large R&D complex. For example, the Uralmash Production Association includes a scientific research and engineering design institute of heavy machine-building which has more than 6000 workers and does business by contract with more than 60 R&D establishments in the country. During the Ninth Plan the PO developed more than 100 prototypes of new machines and equipment.[56] The distinction becomes especially fine when a production association creates new products in small series or single lots and is one of the major producers of this type of product, as with Elektrosila.

On another level, the relations of science-production associations with higher ministerial authorities are not uniform and regularized. In some branches there is no permanent body to lead NPOs. Where such organs exist they sometimes fail to take into account the distinct features of individual associations and regard them all as alike. Some ministries and agencies approach NPOs as ordinary research institutes or industrial enterprises.[57] The lines of subordination also vary. A few NPOs, such as Soiuznauchplitprom and Mikrobioprom, report directly to the ministry (frequently to a deputy minister). The majority, however, operate on a three-link system (NPO--glavk/industrial association--ministry). They report either to one of the glavki or main administrations in their respective ministry or to an all-union industrial association. Plastpolimer provides an example of the latter pattern, which will probably become more common as the ministries reorganize and the glavki are liquidated or transformed into industrial associations. The majority of NPOs function as the first link of management. Yet a number of them conduct from 30 to 100 percent of all R&D done in the branch. In addition some NPOs are essentially all-union associations. These differences are not reflected in their legal status, however. This causes some specialists to argue that certain NPOs should have additional powers and prerogatives compared to other NPOs.[58]

Internal organizational development has also been marked by problems and diversity. The key issue has been the degree of legal authority to be exercised by the central management or head organization as against that retained by the constituent units. "The criteria for establishing a happy median between loose or formal merger and overcentralization of decision making are apparently difficult to arrive at," observes Nolting.[59] The aim of creating these new complexes, it will be recalled, is to break down structural fragmentation, to bring the multiple participants in innovation into closer association and even under common administration.

Meanwhile, the evolution of NPOs up to 1976 shows two negative tendencies. On the one hand, integration stopped far short of the goal of a unified and organic system. Amounting to little more than a mechanical conglomerate of autonomous units, the NPO was transformed into "an administrative superstructure, a superficial link on the path from the ministry and glavk to science and production."[60] Even among the earliest and most tauted NPOs institutional consolidation was slow and incomplete. An investigation of nine major NPOs of this kind by the Academy's Institute of Economics in 1974 found that a council of directors had not yet been formed in three of the complexes. One still lacked a scientific-technical council for the association.[61]

On the other hand, centralization was sometimes carried to an extreme. Constituent units of an NPO were denied any autonomy, even in operational management and control. This situation proved especially debilitating when the association contained subdivisions that were highly diverse and geographically dispersed. As a result the NPO became unmanageable. The decision process became frozen as each unit was forced to go to the highest levels and much time was lost in getting agreements and approvals. In short, association members became caught in the familiar bureaucratic chain from which they were supposedly to be liberated.

Of these two tendencies, the first was the most dominant. The retention of autonomy by components almost everywhere impeded, if not prevented, the development of an integrated planning and management structure for the association as a whole. Pressure subsequently mounted on Moscow authorities to impose greater centralization. Significantly, the official statute on the NPO, which was finally approved by the Council of Ministers on December 30, 1975, stipulates that all units joining an NPO are denied any legal autonomy. At the same time, the ministries and republic officials have been given some discretion in applying this ruling and making exceptions.[62] Intra-associational relations are likely to continue to reflect substantial diversity in practice, if not in form. How successful the 1975 statute will be in overcoming formal merger without leading at the same time to excessive centralization still remains to be seen. Writing in the Academy's main economic journal a year after passage of the statute, two Soviet science experts admit, "While some services are centralized, a system has still not been found of organizing the mutual relations of structural units and the machinery of management for the complex as a whole."[63] Indeed until 1976 NPOs were not even registered as an independent institutional category at the USSR Central Statistical Administration. All accounting was done strictly in terms of their individual structural components.[64]

Underlying these problems of the continuing fragmentation of planning, financing, and management of NPOs are serious and unresolved methodological issues. New integrated performance criteria have not yet been devised. This explains partly, in fact, why ministries and higher planning and financial agencies persist in issuing plans and funds to separate NPO subdivisions. Many performance indicators still relate to the activities of R&D and production units in their previously independent status. Existing indicators do not differentiate between R&D subdivisions that belong to NPOs and those that do not. According to current methods of accounting and reporting, it is not possible to aggregate the activity of organizations that relate to material production and to the world of nonproduction.[65]

To be sure, some efforts are being made in this direction. Some norms have been devised for determining the average length of the research-to-production cycle and are used in measuring the performance of some NPOs. According to Tabachnikas and Skliar, however, these norms are established rather arbitrarily, largely "by eye." No fixed and uniform methodology exists yet for this purpose. In other associations indicators are used to determine the degree to which the research-to-production process has been reduced over time. Taksir points out, however, this kind of norm is of dubious value because reduction of the innovation cycle obviously has a limit.[66] What methodological progress has been made in developing integrated evaluative indicators and norms for NPOs is still largely experimental. Not everyone realizes yet that the NPO is not simply the sum of its parts but represents a qualitatively new type of organization.

Looking back on the first decade of its life, then, we can say that this new institutional form has still not found its proper place in the Soviet scheme. Very few NPOs have approached--much less achieved--the goal of creating an organizationally, technologically, and economically integrated system for promoting innovation. In most, "science" and "production" continue to lead separate lives. The administrative barriers between them have not been effectively broken down. Organization-building has been marked by much confusion and diversity, not to mention bureaucratic opposition and lethargy. In the absence of clear guidelines from the center, branch ministries created NPOs as they saw fit, often obliterating the boundaries between different kinds of research and production complexes. Sometimes NPOs were put together without any systematic research and analysis of design and development problems. Little consideration was given to their place in the context of future directions and needs of the branch as a whole.[67] Initially, the lack of a formal statute permitted needed flexibility and experimentation. It also reduced the danger of putting these new structures into an organizational straitjacket and monolithic mold. More and more, however, the absence of a document establishing the legal status of the NPO and defining its basic functions and principles of organization had prevented the solution of a number of complex problems. The associations were recognized as being frozen in their units, forms, and relations. A new stage of development came in 1976. After confirmation of the NPO statute, Kremlin authorities stepped up efforts to impose greater clarity, order, and direction in the affairs of the associations. The effect of these measures remains to be seen. Taken together they form part of a broader drive to make the Tenth Plan a period of "development not only in breadth but also in depth" for research and production complexes of all kinds, and not just NPOs. As for the latter specifically, they are expected to grow to 200 to 250 by 1980.[68]

At the same time, expectations for the NPOs seem to have cooled. Much of the initial optimism that surrounded them has dissipated. As one Soviet observer noted in the summer of 1976, "One can hardly find now defenders for the view that every branch institute should be turned into an NPO. The opinion is growing slowly but steadily that the number of NPOs in industry cannot be big, perhaps three or four in one ministry." "And if this is so," he continued, "then it is necessary to recognize directly that the NPO is a partial solution to the problem of strengthening the ties between science and production."[69] V. G. Shteingauz also concludes, "The NPO must be regarded as a successful but far from the only form of integrating research with production."[70] The NPO is still expected to play an important--and even increasing--role in accelerating innovation and technical progress, but other integrating structures will have to be developed.

In this light, the growing Soviet interest in establishing specialized introduction organizations whose task is explicitly the implementation and diffusion of new technology and production techniques merits brief discussion. Since this function is not the main job of either scientific or production organizations, a new type of institution is needed for this purpose that is neither a research institute nor an industrial enterprise, some specialists argue. They see innovation--the exploitation and application of new ideas and designs--as a distinct activity that is fundamentally different from both research and production. Hence, they maintain that new technology transfer vehicles are required to perform vital but neglected innovation functions. Such specialized organizations are depicted as the new connecting links between science and industry which serve as important "middlemen" facilitating and mediating the research-to-production process.[71]

Attention to these new structural forms has grown in part because the science-production associations have proven to be more successful at creating new technology than at applying it. While a few NPOs conduct extensive innovation activities, they are the exception rather than the rule. The majority of associations lack the services and staff needed to perform these functions on any meaningful scale. NPOs have other limitations as well that prevent them from acting as significant forces for the mass introduction and diffusion of R&D results. The creation of NPOs strengthens the production ties of only a few research institutes. It does nothing for other branch R&D units that do not belong to the NPOs. They remain as isolated and insulated as before. Moreover, even the most specialized enterprise cannot be satisfied with the services of only one scientific organization to solve all the problems of its technological development. Since NPOs generally produce new items at best in small batches of a 100 or so, their volume of output is clearly insufficient for the needs of the branch as a whole. In addition, the NPOs are obliged to implement their own R&D. Their experimental production capacity is usually too small to handle S&T results produced by outside organizations. In short, the NPOs are closed and relatively confined complexes, walled off from many R&D organizations and production establishments in their branches. What is needed are organizations specializing exclusively in translating R&D into practical use. They must be distinguished by their universality and capability of introducing ideas generated by many sources; they must be places where any R&D unit or industrial plant can turn for assistance.[72]

Actually, the idea of innovation firms is not new. Taksir describes five kinds of organizations that have evolved since the late 1960s and are oriented specifically to the utilization of new technology.[73] One type includes institutions like Energotekhprom within the USSR Ministry of Power and Electrification that are fully geared to develop and transfer R&D results into application. Established in 1965, this experimental production and engineering facility provides a broad array of innovation services in the amount of more than 14 million rubles a year. Besides installing and debugging new products and processes, Energotekhprom trains personnel at client enterprises. The firm also helps scientific institutes formulate their research agendas to incorporate specific requests from industry.

A second type of adaptation-diffusion organization is of a more mixed profile. Along with introducing new technology, it also engages in repair and construction work. Examples include several associations that have been set up by the USSR Ministry of Non Ferrous Metallurgy. Enterprises in this branch are generally not able to conduct technological modernization and improvements on their own. Some of these "introducing" associations have a specific engineering specialty; Uralenergotsvetmet, for example, installs evaporative cooling equipment for metallurgical plants, pneumatic transport systems for loose and pulverized materials, and special pneumatic dust collecting devices. Economic savings from innovations by this one association alone are estimated to have been about 30 million rubles for the period 1971 to 1975.

Soiuztekhosnastika represents the third variety of introduction organization. This association deals mainly in the installation of different interbranch engineering devices. One of its chief tasks is the creation and broad dissemination of a uniform system of standardized multipurpose assembly and readjustable equipment. Soiuztekhosnastika contains several regional divisions that service plants in Moscow, Novosibirsk, Kiev, and other major industrial cities.

A fourth group of innovation organizations is made up of the Centers for Scientific Organization of Labor at various research institutes. Conducting all their work through economic contracts, these centers resemble, to a certain extent, management consulting firms in the West. They serve essentially as organizational intermediaries between R&D establishments and the world of production. Their business involves not only the introduction and diffusion of new technology but also the propagation of knowledge and modern production experience. The Center for Scientific Organization of Labor and Production Management under the All-Union Institute of Economics and Labor Organization in the oil and gas industry falls into this classification.

From a Western perspective, the fifth category of innovation organization identified by Taksir is perhaps the most interesting. This group is comprised of what can best be described as profit maximizing engineering or management consultant firms. They are created and sustained through the private initiative of technological entrepreneurs seeking to exploit S&T advances. Offering a broad profile of services, these organizations exist essentially outside the formal economic system and beyond official planning and control. Paradoxically, this is both their greatest strength and their greatest weakness. In accord with the initial decentralizing spirit of the 1965 economic reform, more than a dozen of these new technical firms sprung up across the USSR. They included, for example, *Fakel* (The Torch) in Novosibirsk, *Novator* (Innovator) in Baku, *Iskra* (The Spark) in Tomsk, *Poisk* (Search) in Severodonetsk, and *Temp* (Tempo) in Moscow. By the early 1970s, however, most of them were forced to close their doors. Others continue to lead a semi-legal life. In general, these institutions have not been stable and surviving additions to the Soviet S&T establishment. This is not because they have been inefficient but, on the contrary, because their success and viability have not been acceptable in ideological and political terms.

Indicative of the nature and fate of these entrepreneurial ventures is the "tale of the Torch."[74] *Fakel* was set up by a few young scientists-entrepreneurs in 1966. It had no budget, no material supplies, no paid staff, and no office space. After compiling a list of prospective consultants and their specialties, the founders simply set up headquarters in a dormitory of the University of Novosibirsk and began soliciting contracts. Consultants would be selected to work on problems in their spare time. Various organizations were paid for the use of their equipment and facilities during non-working hours. The Torch received 3.5 million rubles from 263 contracts for the period up to June 1970. Allegedly, the innovations introduced by it resulted in a savings of 35 million rubles. These included the development of an optimal plan for forest exploitation in

Novosibirsk Province, a system of computer analysis of seismic materials for a local geographical expedition, and an experimental model of a Torch-built swamp vehicle for oil exploration in Western Siberia. Other projects were in such fields as gold extraction, the use of manure, and the development of control devices for the Novosibirsk Power Station. Despite support from the Presidium of the Siberian Division of the Academy of Sciences, not to mention the local Komsomol authorities under whose wing Fakel formally operated, however, this efficient but unconventional organization came under strong attack and eventually closed down in May 1971.[75]

One of the few firms of this kind to have survived (in modified form) is Novator. Formed in 1967 and reorganized by leaders of the Azerbaidzhan Republic in 1971, it has since been put under dual subordination to the Azerbaidzhan Ministry of Local Economy and the State Committee on Inventions and Discoveries. Basically, the firms seeks and screens relatively simple "orphaned inventions" from institutes throughout the USSR that cannot exploit them. By 1976 Novator was doing an annual business of over a million rubles. Since its creation the firm has developed and disseminated more than 120 innovations. Some of these have been awarded state medals, and others have been displayed at the Leipzig international trade fair.[76]

Scientists in particular attempt recurrently to revitalize and legitimize these entrepreneurial firms. Recently in the Academy's main economic journal Taksir and M. Krasnokutskiy argued that these institutions were viable and desirable. They urged that these products of private initiative be turned into state organizations with a firm legal basis.[77] The central issue is the institutionalization, if not bureaucratization, of entrepreneurship. The problem is how to preserve these efficient innovating forms without destroying their spontaneity, independence, and elan vital--the very foundation of their success. Some Soviet specialists recognize that entrepreneurship is frequently associated with specific and special personality traits. Like R. M. Shteinbok, they reason then, "If there are people, there can be organizations as well."[78] The fundamental and problematical elements involved in institutionalizing the innovative spirit are not fully appreciated or addressed.

In general, all five types of introduction organizations are severely limited in their capacity for introducing innovations. There are very few of them. Their legal status remains ill-defined. No formal statute establishes their goals and functions, rights and responsibilities, organizational and administrative relations. Their activity is not properly stimulated, planned, or monitored.[79]

Though there has been renewed interest recently in expanding and developing this net of organizations, Soviet opinion remains hotly divided. Some commentators feel that structures specializing exclusively in innovation have a "right to exist." Given the constraints on existing research and production units, many recognize that new instrumentalities can be useful. Others stress that innovation is the proper function of production units. What is needed is a more favorable climate for innovation at plants. Indeed, the formation of special introduction bodies carries the possible danger that they, like R&D units in the past and even still today, will become organizationally separate from the production sector. As a result, a set of superficial links may be created. Innovation functions themselves may become distorted and exaggerated. The vital interface problems that plague the research-to-production process today would not only persist but be compounded by still another set of administrative barriers. As one observer explains, "Until the economy itself begins to work fully for the introduction of new technology, no organizational structures by themselves will guarantee success."[80] While there is growing awareness that new approaches and perhaps even radical restructuring are needed to provide the stimuli and the opportunities for innovation, there is no clear consensus about what shape these solutions should take.

Financial Developments

In the operating environment of the production establishment, implementation of R&D results is only one of many necessary activities. Because implementation tends to divert physical and financial resources from primary production, and because establishment plans are almost universally ambitious and generally do not include innovation as a primary success indicator, innovation must compete directly with alternative activities. The terms of the competition are increasingly financial. Primary establishment success indicators now are profitability, growth in sales volume, and, to a lesser extent, measures of input productivity and the quality mix of output. Fulfillment and overfulfillment of these target indicators lead to substantial financial bonuses and,less formally, managerial careers.

In general, primary production activities have outrun innovation activities. First, the disruption in normal operations that accompanies the assimilation of new products and processes has not been accounted for, in part because of inadequate preparation at earlier stages of the R&D process. This threatens output and corresponding sales targets. Second, assimilation expenses associated with readying the product for series or mass production are often unanticipated and reduce establishment profitability. For new products in particular, the actual input requirements or costs tend to exceed the planned or projected level. Because prices are generally set administratively in relation to planned cost, sales and profitability performance is lowered, often for years. Ivanov observes that the returns on putting new technological hardware into operation are on the average 55 percent lower than on continued production of old items.[81] As a consequence, plan fulfillment is threatened and performance frequently falls below levels which might have been achieved in the absence of innovation.

To remedy the situation, programs have been developed to accomplish three tasks: (1) compensation for increased costs incurred by the enterprise during the period of retooling and start-up production of new technology; (2) reimbursement of the collectives of the enterprises for losses to the incentive fund due to reduced profitability during the period of assimilation of new products and processes; and (3) rewards for workers at enterprises, assembly and adjustment organizations, and other technology transfer facilities for the development and adoption of new technology.[82] While special financing arrangements have been instituted to achieve the first task, a combination of special incentive programs and alteration in the basic conditions and evaluative criteria influencing motivation have been developed to address the other two. Brief attention is given to several of these programs.

When the producer does face high start-up costs, the superior administrative organ is required to stipulate in the plan adequate sources to cover these costs.[83] First, for "one-off" or very small lot production, expenses may be covered in the price of the product. Second, although increasingly rare, the establishment may receive budget grants comparable to budget grants for R&D projects of especially high priority. The GKNT may be expected to have an important role in administering such grants. A third source is the Fund for the Assimilation of New Technology or the New Products Fund, formed by ministries on the basis of a deduction from total cost of production.[84] Part of this Fund is held by the ministry for application where needs are the greatest. A fourth source is the Fund for the Development of Production, formed at industrial establishments on the basis of their performance. It is used mainly for modernization, automation, and the introduction of new products. Improvements in the performance of the enterprise which lead to better labor productivity, cost reduction, improved quality, and a higher rate of profit can also be financed from this Fund. The bulk of the Fund is used to purchase capital equipment and does not form part of R&D expenditure. It does, however, _ipso facto_ promote the process of innovation. The Fund for the Development of Production is formed from three sources: deductions from enterprise profits; 30 to 50 percent of amortization allowances used for the replacement of capital and differentiated by branches of industry; and receipts from sales by the enterprise of unused and superfluous equipment.[85]

Finally, the introduction of new technology and renovation of plants may be financed through bank loans. Such loans are made available for a period of up to six years under the condition that the costs will be recouped within the indicated time.[86] In general, the New Products Fund, Development Fund, and bank credit account for a large and increasing share of the overall compensation for start-up expenses. However, complaints are frequently voiced in the Soviet press about the administration of each of these programs, and a general consensus seems to prevail that all justifiable if unanticipated start-up costs still are not adequately covered.

When any enterprise "auxiliary" activity, such as innovation, tends to impact adversely on primary indicators of establishment performance, Soviet authorities have often tried to counter this effect with a special incentive program. By doing this, they admit implicitly that parameters such as prices, which indirectly influence the size of basic bonuses, do not reflect accurately the true social benefits of the activity. For example, a new product which initially earns losses may signal a problem in the pricing system rather than an inherently uneconomical product. Rather than address the complex, interrelated factors at the root of the problem, authorities add special programs sequentially as a somewhat crude attempt to compensate for these deficiencies.

Approximately 30 such programs, several of which impact on new technology, are currently in operation. The most important of these, the Fund for the Creation and Introduction of New Technology, has already been described. Other examples are special incentives for the export of Soviet technology abroad and for putting foreign technology into operation. When technology is exported, the Ministry of Foreign Trade allots to science and industry 80 percent of the licenses in foreign currency. Of this amount 30 percent is put at the disposal of the branch ministry (agency) and 50 percent is given to the enterprise (or scientific research institute). These funds can be freely used outside the current state import plan to purchase foreign technology and equipment as well as to acquire technical literature and to finance business trips of experts abroad.[87]

In most cases, (1) a portion of the funds is held by the superior management organ; (2) the size of the fund and its distribution are determined according to formulas, whenever possible related to economic return; and (3) conscious efforts are made to reward only those who actually participate in the introduction of the innovation. The last point has caused dissension. While innovation can be remunerative for the participant, because of the special programs, it can reduce or eliminate the bonuses of the nonparticipant by adversely affecting primary establishment success indicators. Overall, for the establishment manager, Berliner has demonstrated under plausible assumptions that special incentive programs in general will not compensate for the decline in primary bonuses associated with innovation.[88] And should innovation threaten plan fulfillment, resistance to innovation will be extreme.

In recent years, Soviet authorities increasingly have chosen to attack the problem directly by addressing those factors which influence the formation and disbursement of the primary bonus fund. An important factor in formation of the fund is economic substantiation of the parameters which are used to measure performance and, optimally, to guide decision makers. Of these, price formation methodology has drawn the most interest.

Industrial wholesale prices in the Soviet Union are set administratively and left unchanged for varying periods. This facilitates planning and evaluation across periods, but in any case continuous adjustment is administratively impossible. Yet to function as a signal to decision makers, prices also must reflect "socially necessary expenditures of production." With new product innovation, the problem with the traditional system is as simple as it is severe. As cumulative output increases, cost declines for a host of reasons which collectively may be labelled "learning curve effects." While market competition acts to force corresponding declines in prices, fixed prices will yield larger profits as the product becomes increasingly dated.

Formulating price-setting methodology and monitoring its application are the responsibility of the State Committee for Prices. Fairly recently, the Committee has begun to implement measures for introducing at least step-wise or staged price flexibility. The essence of the new techniques is described by Ivanov:

> One of the rules of price formation is that the savings obtained by an innovating enterprise should not exceed 50 percent of the total economic gains. Prices on new articles may change with time, assuring the producer fast write-off of initial start-up costs as well as reasonable profitability of production at all stages of the 'market cycle' of the innovation.
>
> Specifically, prices for items which make only minor improvements or changes in existing products are established in conformity with the price level of their prototypes with adjustments made for the savings effected by the product improvements. Prices for radically new items are established in stages. First, temporary prices are fixed which include planned cost of production of the new article plus a profit margin that is based on the norm of profitability of the enterprise for a given year for its basic output. However, it should not exceed 20 percent or be less than 10 percent of the planned cost of production. After the expiration date of temporary prices (when the initial costs for new production have been written off), permanent wholesale prices are established for new products. In case of high quality products which

> have been awarded the State 'Seal of Quality," prices may include a special incentive markup amounting to 0.5 to 1.0 percent of the profitability norm, but under the condition that this does not increase the producer's share of economic returns by more than 50 percent. This markup is established for a period of 3 years and can be lifted if the article does not meet high quality standards during the next certification.
>
> In turn, permanent wholesale prices on new products may be fixed for a limited period of time and in stages. Such differentiation has the goal of imparting to price formation additional effectiveness as a weapon for removing from the market obsolete products, as well as preserving the fair distribution of economic gains produced by the application of new technology between the producer and the consumer as the cost of production decreases. Step-like, sequentially lowered prices are therefore established for products whose costs are particularly elastic in relation to the volume of the series which saturates the internal market to a high degree and also for products with high rates of obsolescence.[89]

Important elements of this description are the attempt to tie product prices to a measure of quality and the intent to divide the "benefits" or economic returns on a new product between the producer and the consumer, thereby rendering the product advantageous to both. This benefit is transmitted through the effect of higher prices on establishment success indicators and, hence, on the primary bonus fund. And, finally, the step-wise character of pricing is intended to promote product turnover. Imparting price flexibility by administrative means is costly and cumbersome, but promises benefits.

Other recent efforts relate the size of primary bonus funds to technological advance and the evaluation of measures of labor productivity and product quality to primary success indicators. Encouraging growth in labor productivity is designed to induce the establishment to seek out process innovations. Greater emphasis on product quality indicators is intended to promote product innovation. Again both these measures depend on administrative evaluation procedures. Ivanov describes the system as follows:

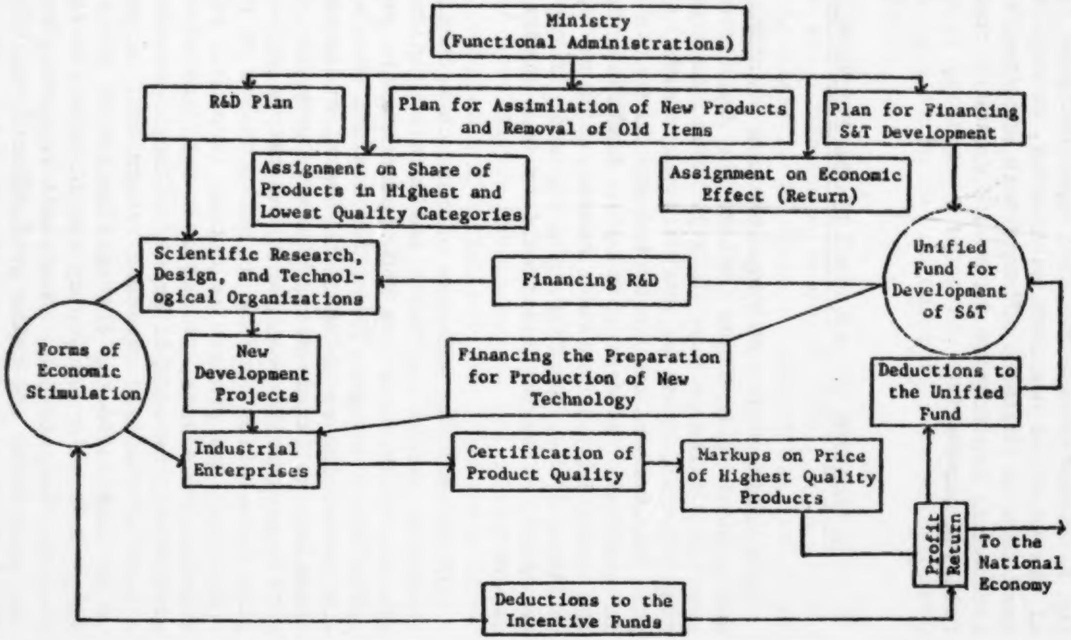
> Fulfilling plans for the introduction of new technology at enterprises has a direct effect on the financial indicators of their economic activity, and in particular on the generation of incentive funds and funds for social-cultural and housing programs. This link is realized by means of periodic certification of products manufactured by plants. The results of this certification are used to adjust the base standards for forming these funds. During the Ninth Five Year Plan, for example, enterprises which set for themselves higher targets than those of the plan were permitted to increase their allocations to the incentive funds by 2 to 9 percent for each one percent increase in the production of high quality output, calculated on the basis of its total output. Also if the output of high quality products exceeded the norms of the plan, they could increase the allocations by 1 to 4 percent depending upon the share of this production to total output. Conversely, incentive allocations were reduced by 3 to 10 percent for each one percent decrease of high quality production as compared with planned targets. In addition, for each one percent increase in the volume of low quality output above the permitted norm, these allocations were cut by 1 to 10 percent depending on the share of low quality production in the total output.[90]

Such procedures are also costly to administer but allegedly have worked.

Finally, Soviet authorities have introduced a provision which stipulates that a portion of the primary bonus fund is to be used for lump sum payments to individuals or collectives as a reward for particularly noteworthy achievements. Innovation is prominent on the list of such achievements. We do not know the extent to which such payments are actually made to reward innovation activity, but they do offer the potential of a flexible and effective stimulus, at least from the perspective of the recipient. However, the caveat applicable to the Fund for the Creation and Introduction of New Technology is also pertinent here. A lump sum payment may make the participant better off, but if the innovation should cause the entire bonus fund to shrink, the labor force as a whole will suffer. Indeed, the motivating effect of all these special incentives for innovation is limited. The statutory ceilings on individual bonus earnings are such that no person may receive an excess of 90 to 110 percent of his base salary in bonuses of all kinds. The relative balance of risk and reward associated with innovation, Berliner concludes, still tends to motivate Soviet decision makers and managers to discriminate against innovation in favor of alternatives that involve no change in products or processes.

In sum, throughout this section we have described briefly (and incompletely) elements of Soviet planning, managerial, and financial policy which influence the degree and rate of new technology utilization. While noting that the system must in fact be formulated and set in operation as an integral unit, we have been forced to analyze each unit separately. Yet, for traditional practice, this approach does not severely distort reality, since the stages of R&D, the participants, and the various policy makers all tend to be disjointed. However, we note in passing that experiments are underway in certain ministries to "unify" not only the stages of R&D but also the entire policy-making process. The system, depicted schematically in Figure 11-4, originated in the electrical engineering industry. Planning is to be "continuous," accounting for all stages of the innovation process. Similarly, financing originates in a Unified Fund for the Development of Science and Technol-

FIGURE 10-4 BASIC SCHEME OF THE SYSTEM OF PLANNING, FINANCING, AND ECONOMIC STIMULATION OF S&T DEVELOPMENT IN THE SOVIET ELECTRICAL ENGINEERING INDUSTRY


Ministry
(Functional Administrations)
R&D Plan
Plan for Assimilation of New Products and Removal of Old Items
Plan for Financing S&T Development
Assignment on Share of Products in Highest and Lowest Quality Categories
Assignment on Economic Effect (Return)
Scientific Research, Design, and Technological Organizations
Financing R&D
Unified Fund for Development of S&T
Forms of Economic Stimulation
New Development Projects
Financing the Preparation for Production of New Technology
Deductions to the Unified Fund
Industrial Enterprises
Certification of Product Quality
Markups on Price of Highest Quality Products
Profit
Return
To the National Economy
Deductions to the Incentive Funds

Source: G. A. Dzhavadov, Upravleniye nauchno-tekhnicheskim progressom (Moscow, 1975), p. 32.

ogy, again accounting for all stages. Within this system planning, finance, management, incentives, and other elements are to be closely integrated. This system does represent a radical departure from traditional practice and has been successful, though it has been slow to diffuse. The pattern and impact of its broadening application in Soviet industry should be followed carefully.

EVALUATION OF R&D RESULTS AND PERFORMERS

The basic notion of comprehensive planning of R&D and economic activities implies the ability to predetermine results in some detail. Thus, in the planning process, a set of evaluative criteria, the targets themselves, are generated and in fact are used in assessment at designated plan deadlines. Because the resulting performance rewards, such as the size of bonus funds, sometimes are planned, it may even be said that evaluation itself to some extent is predetermined.

Of course, the accuracy of this characterization increases as the precision and detail of planning increase, which occurs as R&D approaches the production assimilation stage. Thus, for design, development, and production establishments formal evaluative criteria are utilized which, whenever possible, incorporate quantitative measures. Indicators employed in plan formulation (volume of work, number of projects completed) and project selection (economic return, technical measures, social criteria) are also used in evaluating the establishment. Though calculations of actual or realized economic return are, in principle, to be made following the application of R&D results in production or use, they are in practice rarely computed or recorded. Decisions regarding evaluation and incentives are taken predominantly on the basis of planned or projected estimates of return, not on real results and savings.

The fact that individual compensation to some extent is tied to plan and project measures implies that evaluation of employees and participants proceeds in similar fashion. Of course, subjective judgment always enters into personnel evaluation, but attempts are made to maximize reliance on objective criteria. Performance in meeting quantitative plan targets affects not only income but also careers of production managers, for example, and thus is held to be an indicator of general managerial capability.

As planning becomes less precise and detailed in applied and fundamental research, there is a commensurate increase in reliance on subjective evaluation. In practice, a mix of objective and subjective criteria is employed to take into account the originality and long-range promise of R&D, its economic and social usefulness, etc.[91] At the same time, the procedure for performance evaluation tends naturally to be internalized in research facilities, as the researcher's professional colleagues may be the only group qualified to judge performance. Still, though, the formality and hierarchical procedures characteristic of most Soviet bureaucracies are also present in the research evaluation process. The results of the evaluation, in turn, are an important input in the decision to continue, modify, or terminate projects which extend beyond standard plan periods. Recommendations of consultative organs and expert groups are transmitted up the hierarchy to respective GKNT, Academy, and Ministry authorities for official determination of future establishment and project directions.[92]

Relatively little information is available concerning performance evaluation criteria and procedures for individual scientists. Presumably, they differ across facilities. We briefly describe below the example of the evaluation system developed and used at the Scientific Research Institute of Physical Chemistry imeni L. Ya. Karpov.[93] The Karpov system, as it has come to be known, is gradually being adopted in other Soviet research facilities.

Salary at the Karpov Institute depends on academic degree attained, length of service, and results of work. To evaluate the last element, a "certification" commission convenes which includes leading scientists and representatives of management and social organizations. The commission evaluates employees not less than once every three years. A 10 point rating system is used, and the following criteria are employed to evaluate the individual:

1. Professional qualifications
2. Diligence at work
3. Prospects for further activity
4. Originality of research
5. Theoretical level of research
6. Experimental level of research
7. Value of research for theory
8. Value of work for practice
9. Ability to work independently
10. Ability to organize work for subordinates
11. Participation in work of technology utilization
12. Participation in social activities
13. Direct participation in experiment work[94]

The commission makes two kinds of recommendations as a result of its assessment: (1) maintain or modify job tasks; and (2) increase or decrease salary or keep it at the present level. The results of the evaluation are approved by the learned council of the institute. The decision of the council is final.[95]

In general, Soviet procedures for evaluating R&D results and performers tend to be formal and highly structured. The work of both individuals and institutions is evaluated primarily in terms of their formal fulfillment of thematic and financial plans, not on the basis of the real value of their S&T achievements. There is a strong tendency therefore to propose "safe" and relatively minor themes, whose parameters are fairly well known and results more certain. As Academician Ya. Kolotyrkin comments, "An institute can fulfill its subject and financial plans year after year without contributing anything to technical progress."[96]

Recently efforts to tie R&D planning and resource allocation, management and incentive programs to end results--the ultimate application of technology in new products and processes--have mounted. Throughout this study we have mentioned the increasingly ubiquitous though still ambiguous measure of "economic return or effectiveness." If the utilization of R&D was almost ignored in science policy in the past, then since the late 1960s it has come to have almost exaggerated emphasis. There are important limitations, however, on the utility of practical application as a criterion for evaluating R&D results and performers. Some science specialists contend that R&D organizations should not be evaluated in terms of the final stages of the innovation process in which they still have little direct participation, much less control. Furthermore, the evaluation of results and real returns must be long range because of the necessarily protracted process of moving results from the lab into use. Hence, the operational character of evaluation is lost, and its motivating role is diminished.[97] As O. I. Volkov notes, scientific R&D organizations cannot be evaluated by the same criteria as production establishments. They require an independent system of indicators, instruments, and special organization of management which, though closely linked with the economy, possesses at the same time necessary autonomy.[98] Science has its own internal development needs which must be attended to, besides its external relations and linkages with production.

DIFFUSION OF R&D RESULTS

In the Soviet economy, under traditional organizational and operating principles, diffusion of new technology should not differ markedly from innovation. That is, the first introduction and subsequent introduction are not so sharply distinguished in the USSR as in the West. Part of the reason for this is organizational. When branch institutes or design bureaus are independent, they are meant to serve impartially all production facilities in the branch, and proprietary rights over innovations are not associated with the first introduction or use. Innovation may be introduced simultaneously or sequentially in facilities, with little advantage accruing to the first user.

The absence of competitive pressures in the Soviet economy also means that the economic viability of the noninnovator is not automatically threatened by its failure to act. The production facility in the USSR is responsible to its administrative superiors. For the most part the facility is competing not against other facilities but instead against its own performance in previous periods. Because targets tend to be set in relation to earlier own-facility results, and because of conditions of general excess demand, facilities of widely differing productivity levels and innovative postures can coexist in the Soviet economy for indefinite periods.

Today these situations are changing somewhat, in part because of a conscious desire of the Soviet leadship to encourage more rapid technology diffusion. Organizationally, the affiliation of R&D and production establishments, as in the science-production association, tends to distinguish an innovation from a diffusion process. Innovation may be thought of as occurring when the NPO plant successfully introduces the technology, while the NPO leaves the problem of diffusion to other branch plants. Similarly, to generate pressure for more rapid process innovation, Soviet authorities are attempting to rely as much as possible on branch-wide performance criteria for target formulation. Of course, branch standards have always been the ideal, and the process is slowed by the fact that inefficient plants are not placed in a severely disadvantageous position. Yet the greater accent now placed on branch-wide performance comparisons may ultimately have a favorable impact on technology diffusion.

In large part, however, the factors outlined previously which influence technology delivery and utilization by the first producer similarly influence succeeding adopters. Plans may stipulate introduction and in general are the basic coordinating and motivating mechanism for diffusion. Organizational and financial mechanisms may be employed to create a favorable disposition toward innovation in all potential adopters. The impact of clearly superior economic performance is exemplified by the experience of developing new ceramic tile manufacturing technology:

> In this case it is also vital to note that the socio-economic consequences of replacing the old technology of producing ceramic tiles in tunnel kilns with a new technology using automated conveyer assembly lines with slit kilns were so obvious that adoption of the new method in industry ... not only encountered no resistance, but, on the contrary, a whole number of enterprises and agencies sought additional ways to move up the fixed schedule for putting this system into operation.[99]

In certain instances, however, the age of a product determines the applicability of a special innovation-related program. For example, compensation for high start-up costs from the Fund for Assimilation of New Technology is only permitted for new products, where "newness" is defined bureaucratically to apply "if (a) it is the first instance of the product's production in the USSR, or (b) no more than two years have elapsed since it was first introduced in the USSR."[100]

Special Soviet programs to facilitate diffusion resemble those in any advanced industrial country.

Technical information services, managed by the All-Union Institute for Scientific and Technical Information (VINITI), are among the best in the world. VINITI disseminates Soviet journals, translation journals, and comprehensive abstracts of foreign and domestic publications, and assists in publicizing patents. Most industrial ministries have similar agencies. Academy, university, ministries, and S&T societies host frequent technical conferences which facilitate personal interaction, a potent means of technology transfer. Actual transfer of personnel with the direct or indirect intent of transferring technology tends to occur less frequently, and is particularly rare across ministerial boundaries. Standardization programs, such as those concerning design documentation, facilitate transfer but are a relatively recent development. Finally, a common Soviet technique of technology diffusion which avoids many of the administrative problems described previously is the construction of entirely new facilities which "embody" the new technology. However, the performance of the Soviet construction industry is itself quite poor, especially concerning lead times, and the shift of investment funds away from new construction to reconstruction of facilities reduces the scope for this approach.

In sum, the Soviet innovation and diffusion processes are rendered similar, if not indistinguishable, by the nature of Soviet economic organization and administration. The general absence of competitive pressures in particular is a severe deterrent to rapid diffusion. Special programs designed to encourage internal technology transfer, particularly relating to information and (potentially) standardization, can alleviate some of the problems but are not, in our view, sufficiently effective to overcome barriers to innovation created by fundamental attributes of the Soviet economic mechanism.

FOOTNOTES

1. See L. S. Blyakhman, ed., *Voprosy ekonomiki i planirovaniya nauchnykh issledovaniy* (Leningrad, 1968), p. 93; N. I. Dryakhlov, S. I. Nikishov, Yu. K. Pletnikov, and S. V. Shakhardin, eds., *Nauchno-tekhnicheskaya revolyutsiya i obshchestvo* (Moscow, 1973), p. 446; V. P. Aleksandrova, ed., *Problemy planirovaniya i effektivnosti razvitiya nauki i tekhniki v ukrainskoy SSR* (Kiev, 1976), p. 50; V. Sominskiy and L. Blyakhman, eds., *Ekonomicheskiye problemy povysheniya effektivnosti nauchnykh razrabotok* (Leningrad: Lenizdat, 1972), p. 177; V. N. Arkhangel'skiy, *Organizatsionno-ekonomicheskiye problemy upravleniya nauchnymi issledovaniyami* (Moscow, 1977), p. 33; V. I. Kushlin, *Uskoreniye vnedreniya nauchnykh dostizheniy v proizvodstvo* (Moscow: Ekonomika, 1977), p. 3; Nolting, *Sources of Financing the States of the Research, Development, and Innovation Cycle in the USSR*, p. 3.

2. Kanygin, *Nauchno-tekhnicheskiy potentsial*, p. 225.

3. L. S. Blyakhman, "Nauka kak otrasl proizvodstvennoy deyatel'nosti," in Blyakhman, ed., *Voprosy ekonomiki i planirovaniya nauchnykh issledovaniy*, p. 15.

4. Berliner, *The Innovation Decision in Soviet Industry*, pp. 103-104.

5. K. I. Taksir, *Integratsiya nauki i proizvodstva pri sotsializme* (Moscow: Znaniye, 1975), p. 14; Kushlin, *op. cit*., p. 122.

6. V. G. Shteingauz, *Ekonomicheskiye problemy realizatsii nauchno-tekhnicheskikh razrabotok* (Moscow. 1976), p. 118.

7. A. Zalkind, "Akademiya dlia 'neakademicheskikh' nauk," *Literaturnaya gazeta*, 12 (March 24, 1976), p. 11.

8. A. N. Bortnyakh, ed., *KPSS i sovremennaya nauchno-tekhnicheskaya revolyutsiya* (Kiev, 1974), pp. 379 380.

9. Zalkind, *op. cit.*

10. See Tom Burns, "Models, Images, and Myths," in William H. Gruber and Donald G. Marques, eds., *Factors in the Transfer of Technology* (Cambridge, Massachusetts: MIT Press, 1969), pp. 11-23. One of the best discussions of Soviet views of innovation is by Kanygin. See his *Nauchno-tekhnicheskiy potentsial*, pp. 151-213.

11. V. I. Berlozertsev, "Soedineniye nauchno-tekhnicheskoy revolyutsii s preimushchestvami sotsializma," in *Problemy soyedineniya dostizheniy nauchno-tekhnicheskoy revolyutsii s preimushchestvami sotsializma* (Voronezh, 1974), pp. 11-12.

12. Kanygin, *Nauchno-tekhnicheskiy potentsial*, p. 222.

13. Berliner, *op. cit.*, p. 140.

14. Zavlin et al, *Trud v sfere nauki* (Moscow, 1973, 2nd edition), pp. 123-125, 129, 206-207.

15. *Ibid.* (First edition), p.

16. Berliner, *op. cit.*, p. 116.

17. Zaleski et al, *Science Policy in the USSR*, p. 93.

18. D. Bobryshev and Ye. Nisevich, *Setevyye metody v upravlenii* (Moscow, 1973), p. 14.

19. See Robert W. Campbell, "Management Spillovers from Soviet Space and Military Programs," *Soviet Studies*, XXIII, 4 (1972), pp. 586-607.

20. See Yu. I. Maksimov, "Second Wind for Network Methods," *Ekonomika i organizatsiya promyshlennogo*

proizvodstva, 4 (July-August 1976), pp. 205-211; V. G. Afanasyev and V. S. Chesnokov, "Sistemy tselevogo planirovaniya--instrument effektivnogo upravleniya nauchnymi issledovaniyami," in Nauchnoye upravleniye obshchestvom (Moscow: Mysl', 1972), VI, pp. 268-331; D. M. Gvishiani, ed., Voprosy teorii i praktiki upravleniya i organizatsii nauki (Moscow: Nauka, 1975), pp. 17-22, 82-95; G. M. Dobrov et al, Programmno-tselevoy metod upravleniya v nauke, pp. 24-27.

21. V. I. Dobuzhinskiy, D. D. Katanov, and E. L. Rokhvarger, "Razrabotka novoy tekhnologii keramicheskikh plitok" (Development of A New Technology of Ceramic Tiles), p. 7. Soviet Side of the Joint Soviet-American Working Subgroup on Planning and Management of Scientific Research and Development. Unpublished (draft) paper, 1976.

22. Yefimov et al, "Development and Realization of A Program of Comprehensive Mechanization of Fundamental and Auxiliary Processes of Production at the Moscow Production Association ZIL," pp. 7-8.

23. Zaleski et al, Science Policy in the USSR, p. 280.

24. Gvishiani, "Centralized Management of Science: Advantages and Problems," p. 103.

25. Ivanov, "Preodoleniye prepyatstviy i stimulirovaniye pri vnedrenii novoy tekhniki i novykh metodov upravleniya," p. 10.

26. Ibid.

27. Ibid., p. 12.

28. A. G. Orlov, Oplata truda rabotnikov nauki (Moscow: Nauka, 1973), p. 52.

29. Ivanov, op. cit., p. 11.

30. Ibid.

31. *XXIV Syezd KPSS: Stenograficheskii otchet* (Moscow: Politizdat, 1971), I, pp. 80-81.

32. L. M. Bashin, "Ekonomicheskiye problemy vnedreniya novoy tekhniki," *Voprosy izobretatel'stva*, 7 (1975), p. 12.

33. See G. D. Anisimov, L. S. Glyazer, A. M. Omarov, V. G. Pankratyev, and M. P. Ring, *Nauchno-tekhnicheskiy progress i khozyaystvennaya reforma* (Moscow: Nauka, 1969), pp. 119-127; "The Quality of Designs," *Pravda* editorial, May 13, 1977.

34. L. S. Blyakhman, "The Association: Experience and Prospects," *Pravda*, December 1, 1971.

35. Ivanov, *op. cit.*, p. 21.

36. *Ibid.*

37. *Ibid.*, p. 22.

38. K. I. Taksir, *Nauchno-proizvodstvennyye ob"yedineniya* (Moscow: Nauka, 1977), pp. 42-53, 57-58; Yu. Subotskiy, *Novyi etap razvitiya ob"yedineniy v promyshlennosti* (Moscow: Znaniye, 1973), p. 26; E. I. Gavrilov, *Ekonomika i effektivnost' nauchno-tekhnicheskogo progressa* (Minsk: Vyshaya shkola, 1975), p. 290; L. N. Andrukhovich, *Upravleniye kachestvom* (Moscow: Znaniye, 1976), p. 47.

39. Taksir, *Nauchno-proizvodstvennyye ob"yedineniya*, p. 57; G. A. Dzhavadov, *Upravleniye nauchno-tekhnicheskim progressom* (Moscow: Znaniye, 1976), p. 23.

40. Taksir, *op. cit.*, p. 132.

41. V. Pokrovskiy, "Perestraivayas' na marshe," *Sotsialisticheskaya industriya*, July 13, 1977, p. 2.

42. Taksir, *op. cit.*, pp. 125-154; Louvan E. Nolting, *The 1968 Reform of Scientific Research, Development, and Innovation in the USSR*, U.S. Department of Commerce, Foreign Economic Report No. 11 (Washington D.C., 1976), p. 16; Shteingauz, *op. cit.*, pp. 120-

122, 127 and her "Novye organizatsionnyye formy svyazi nauki s proizvodstvom," in *Ekonomika i organizatsiya promyshlennogo proizvodstva*, 3 (1973), pp. 46-47; M. A. Yudelevich and M. A. Gusakov, "Puti sokrashchenii tsikla 'issledovaniye-proizvodstvo,'" in Blyakhman, ed., *Voprosy ekonomiki i planirovaniya nauchnykh issledovaniy* (Leningrad: Lenizdat, 1968), pp. 93-95; G. A. Dzhavadov, "Nauchno-proizvodstvennyye ob"yedineniya--forma integratsii nauki, tekhniki, proizvodstva," *Sovetskoye gosudarstvo i pravo*, 1 (1975), p. 37, 43-44; Andrukhovich, *op. cit.*, pp. 48-50; Sominskiy and Blyakhman, *Ekonomicheskiye problemy povysheniya effektivnosti nauchnykh razrabotok*, pp. 179-180.

43. Berliner, *op. cit.*, p. 135.

44. See Dzhavadov, "NPO--forma integratsii nauki, tekhniki, proizvodstva," p. 37; Yu. V. Subotskiy, *Razvitiye ob"yedineniy v promyshlennosti: Voprosy teorii i metodologii* (Moscow, 1977), pp. 66-67; V. Kochikyan and V. Kushkin, "Osnovy khozyaystvennogo rascheta v nauchno-proizvodstvennykh ob"yedineniyakh," *Planovoye khozyaystvo*, 7 (1977), pp. 25-26; K. I. Taksir, "Nauchno-proizvodstvennyye ob"yedineniya," *Voprosy ekonomiki*, 11 (1972), pp. 48-49 and his *Nauchno-proizvodstvennyye ob"yedineniya*, p. 39; Pokrovskiy, "Perestraivayas' na marshe," p. 2.

45. Taksir, *Nauchno-proizvodstvennyye ob"yedineniya*, pp. 35, 39-40; Shteingauz, *Ekonomicheskiye problemy realizatsii nauchno-tekhnicheskikh razrabotok*, p. 124; V. N. Arkhangel'skiy, *Planirovaniye i finansirovaniye nauchnykh issledovaniy* (Moscow: Finansy, 1976), pp. 158-160; Kochikyan and Kushkin, *op. cit.*, p. 26.

46. Yu. Kanygin and S. Kostanyan, "Nauchno-proizvodstvennyi tsikl," *Voprosy ekonomiki*, 12 (1976), p. 61.

47. Yu. M. Mikhnevich, *Ekonomicheskiye problemy upravleniya nauchno-tekhnicheskim progressom* (Leningrad, 1974), p. 57.

48. Taksir, *Nauchno-proizvodstvennyye ob"yedineniya*, p. 110.

49. *Ibid.*, p. 111 and Arkhangel'skiy, *Planirovaniye i finansirovaniye nauchnykh issledovaniy*, p. 162.

50. These tasks are listed in the statute on the NPO. See "Polozheniye o nauchno-proizvodstvennom ob"-yedinenii," *Sobraniye postanovleniy pravitel'stva SSSR,* 2 (1976), pp. 24-25. See also Subotskiy, *Razvitiye ob"yedineniy v promyshlennosti*, p. 67 and Dzhavadov, "NPO--forma integratsii nauki, tekhniki, proizvodstva," pp. 38-39.

51. Taksir, *Nauchno-proizvodstvennyye ob"yedineniya*, pp. 43-79.

52. *Ibid.*, pp. 38-39, 74-79; Kushlin, *Uskoreniye vnedreniya nauchnykh dostizheniy v proizvodstvo*, p. 111.

53. *Ibid*. See also Pokrovskiy, "Peretraivayas' na marshe," p. 2.

54. Taksir, *Nauchno-proizvodstvennyye ob"yedineniya*, pp. 48-49, 139-140.

55. Ibid., pp. 32, 37 and L. A. Bulochnikova et al, eds., *Problemy sovershenstvovaniya upravleniya sotsialisticheskoy ekonomikoy* (Moscow: Mysl', 1976), pp. 135-136.

56. Taksir, *Nauchno-proizvodstvennyye ob"yedineniya*, pp. 17-22.

57. K. I. Taksir, "Nauchno-proizvodstvennyye ob"yedineniya," *Voprosy ekonomiki*, 11 (1972), p. 50.

58. Taksir, *Nauchno-proizvodstvennyye ob"yedineniya*, pp. 36, 55-56, 78, 157-158 and Shteingauz, *Ekonomicheskiye problemy realizatsii nauchno-tekhnicheskikh razrabotok*, p. 124.

59. Nolting, *The 1968 Reform*, p. 16.

60. Sominskiy and Blyakhman, *Ekonomicheskiye prob-*

lemy povysheniya effektivnosti nauchnykh razrabotok, pp. 188-189 and Dzhavadov, "NPO--forma integratsii nauki, tekhniki, proizvodstva," p. 40.

61. Taksir, *Nauchno-proizvodstvennyye ob"yedineniya*, pp. 54-55.

62. "Polozheniye o NPO," p. 23.

63. B. Tabachnikas and M. Sklyar, "Khozyaystvennyy raschet nauchno-proizvodstvennykh ob"yedineniy," *Voprosy ekonomiki*, 12 (1976), p. 73.

64. Kushlin, *Uskoreniye vnedreniya*, p. 112. In its decision approving the NPO statute the USSR Council of Ministers stipulated that the USSR Ministry of Finance and the Central Statistical Administration had to draw up within six months appropriate bookkeeping and statistical reporting forms for the NPOs.

65. See Nolting, *The 1968 Reform*, p. 16; Gavrilov, *Ekonomika i effektivnost' nauchno-tekhnicheskogo*, pp. 297-305; B. Tabachnikas and M. Sklyar, "Otsenka raboty i printsipy obrazovaniya fonda material'nogo pooshchreniya nauchno-proizvodstvennykh ob"yedineniy," *Planovoye khozyaystvo*, 2 (1974), pp. 123-124.

66. Tabachnikas and Sklyar, "Khozyaystvennyy raschet NPO," p. 77 and Taksir, *Nauchno-proizvodstvennyye ob"yedineniya*, pp. 101-112.

67. Gavrilov, *op. cit.*, pp. 294-295; Mikhnevich, *op. cit.*, pp. 71, 85.

68. Subotskiy, *Razvitiye ob"yedineniy v promyshlennosti*, p. 5 and Taksir, *Nauchno-proizvodstvennyye ob"yedineniya*, p. 158.

69. R. M. Shteinbok, "Komu vnedryat' novuyu tekhniku?" *Ekonomika i organizatsiya promyshlennogo proizvodstva*, 6 (1976), pp. 78-79.

70. Shteingauz, *Ekonomicheskiye problemy realiza-*

tsii nauchno-tekhnicheskikh razrabotok, p. 125.

71. See Taksir, *Sushchnost' i formy soyedineniya nauki s proizvodstvom pri sotsializme* (Moscow: Vysshaya Shkola, 1974), pp. 92-104; V. Pavlyuchenko, "Ot stola konstruktura do zavodskogo konveiera," *Pravda*, June 13, 1971 and his *Ekonomicheskiye problemy upravleniya nauchno-tekhnicheskim progressom* (Moscow: Nauka, 1973), pp. 202-213; Shteinbok, *op. cit.*, pp. 76-85; Kanygin, *Nauchno-tekhnicheskiy potentsial*, pp. 237-241.

72. See Shteinbok, *op. cit.*, pp. 79-80 and L. Davydov and R. Shteinbok, "Formy organizatsii vnedreniya novoy tekhniki," *Voprosy ekonomiki*, 9 (1977), p. 134.

73. See Taksir, *Sushchnost' i formy soyedineniya nauki s proizvodstvom pri sotsializme*, pp. 92-104 and his *Nauchno-proizvodstvennyye ob"yedineniya*, pp. 24-25.

74. See the excellent article by John Lowenhardt, "The Tale of the Torch: Scientists-Entrepreneurs in the Soviet Union," *Survey*, XX,4 (93) (Autumn 1974), pp. 113-121.

75. *Ibid.*, pp. 117-118.

76. K. Taksir and M. Krasnokutskiy, "Formy organizatsii vnedreniya novoy tekhniki," *Voprosy ekonomiki*, 1 (1977), p. 50; V. Pokrovskiy, "Novaya tekhnika: Dorogi i porogi," *Ekonomicheskaya Gazeta*, 10 (March 10, 1976), p. 10.

77. Taksir and Krasnokutskiy, *op. cit.*, p. 50.

78. Shteinbok, "Komu vnedryat' novuyu tekhniku," p. 80.

79. K. I. Taksir, *Integratsiya nauki i proizvodstva pri sotsializme* (Moscow: Znaniye, 1975), pp. 47-48.

80. *Ekonomika i organizatsiya promyshlennogo pro-*

izvodstva, 5 (1977), p. 160. These difference of view were expressed in the debate in this issue of EKO (pp. 143-146) under the subject, "Komu vnedryat' novuyu tekhniku?" (To Whom Should the Introduction of New Technology Be Entrusted?) This was the title of Shteinbok's essay that appeared in the journal the year before. The discussion in the May 1977 issue contains reactions to Shteinbok's article and call for specialized introduction organizations for new technology.

81. Ivanov, op. cit., p. 7.

82. L. M. Gatovskiy, Nauchno-tekhnicheskiy progress i ekonomika razvitogo sotsializma (Moscow: Nauka, 1974), p. 202.

83. "USSR Short Answers," p. 57.

84. Berliner, The Innovation Decision in Soviet Industry, p. 271.

85. Zaleski et al, Science Policy in the USSR, p. 119.

86. Ivanov, op. cit., p. 8.

87. Berliner, op. cit., p. 493 and Ivanov, op. cit., pp. 8-9.

88. Berliner, op. cit., p. 488.

89. Ivanov, op. cit., p. 7.

90. Ibid.

91. "USSR Short Answers," p. 25.

92. Ibid., p. 29.

93. P. A. Sedlov, Material'noye stimulirovaniye rabotnikov za sozdaniye i osvoyeniye novoy tekhniki (Moscow: Ekonomika, 1975), p. 55.

94. *Ibid.*, p. 56.

95. Orlov, *Oplata truda rabotnikov nauki*, p. 118.

96. Ya. Kolotyrkin, "O rezervakh uvelicheniya otdachi ot nauchnogo potentsiala," *Kommunist*, 8 (1974), p. 53.

97. A. Konson, "Pokazateli nauchno-tekhnicheskoy deyatel'nosti NII, KB, i NPO i proizvoditel'nosti truda nauchnykh rabotnikov," *Planovoye khozyaystvo*, 3 (1976), pp. 133-140.

98. O. I. Volkov, *Planovoye upravleniye nauchno-tekhnicheskim progressom* (Moscow: Nauka, 1975), p. 157.

99. Dobuzhinskiy et al, *op. cit.*, p. 12.

100. Berliner, *op. cit.*, p. 200.

XI CURRENT ISSUES AND TRENDS IN SOVIET SCIENCE POLICY

Science policy has become a subject of continuous discussion and vigorous debate in the USSR since at least the mid-1960s. Indeed, the great attention given to S&T issues in domestic and foreign policy reflects the extent to which a perceived "technological imperative" has come to dominate and divide the Kremlin leadership. While many of the basic problems themselves are not new, Soviet perceptions of them have broadened and changed along with the scope of official motivation to use science and technology more effectively as an instrument of policy and tool of economic progress. As a result the political leadership has begun to reexamine some of the fundamental assumptions, managerial attitudes, and organizational arrangements which underlay science policy in the past and to adopt some new approaches and directions for the future.

THE CONTEMPORARY SCIENCE POLICY DEBATE: CONTEXT AND CONTENT

The current debate has been prompted by two important cognitive discoveries. First is the rather belated awakening of the ruling elite to the full significance of the development and role of science and technology in the world, roughly since mid-century. These changes have been dubbed the "contemporary scientific and technological revolution" (hereafter abbreviated as STR), largely a euphemism for the computer age. The changing conditions and new demands associated with this new stage of industrial revolution are seen as placing unprecedented importance on scientific and technical progress. Such progress becomes not only the key force driving modern society forward but also a major arena of competition between the world's two opposing social systems. Underlying the notion of the STR is also implicit--and sometimes explicit--recognition of Russia's relative backwardness and growing technology gap with the West, especially the United States. As a letter of appeal from dissident but concerned Soviet scientists to Party and government leaders in March 1970 noted frankly, with respect to the computer age: "We are simply living in a different era. The second industrial revolution came along and now, at the onset of the seventies, we see that far from having overtaken America, we are dropping further and further behind."[1] Thus, a "historic" task facing the USSR today, as defined by General Secretary Brezhnev at the 1971 Party congress and reaffirmed by the 1976 congress, is "to combine organically the achievements of the STR with the advantages of the socialist economic system, to unfold more broadly our own, intrinsically socialist forms of fusing science with production."[2]

Second, there has also been growing realization that the Soviet economy is approaching the limits of "extensive" growth and entering a new era that calls for more "intensive" methods of development. Declining supplies of manpower and material resources require a basic shift in development strategy and greater emphasis on qualitative improvements rather than quantitative increases of inputs as the main source of future growth. Already at the end of the 1960s, Brezhnev declared firmly that intensification "becomes not only the main way but the only way of developing our economy." Moreover, in this approach he told the 1971 Party congress, "the acceleration of S&T progress forges into first place both from the point of view of current tasks and of the long-term future." Premier Kosygin similarly insisted at the 1976 congress that without faster translation of S&T into production "the economy can no longer successfully advance along the path of intensification and quality improvement."[3]

International and domestic pressures have combined, therefore, to make the accleration of S&T progress a major issue of the 1970s and beyond. Just as he had defined this to be the "key task" of economic policy in 1971, Brezhnev also listed it first among the "key problems" of the period of the Tenth Five Year Plan (1976-1980). Indeed, the General Secretary affirmed, "In our entire economic development perhaps no tasks today are more urgent and more important."[4]

There is also enhanced awareness in Moscow of the need to raise the quality of R&D planning and management. No longer can science policy afford to be built on the basis of "subjective evaluations and wishes," contends V. A. Trapeznikov, a first deputy chairman of the GKNT. Gvishiani describes as a major task of the day, "To put the development of science itself on a strictly scientific basis." Dr. Semyon Mikulinsky, a leading science policy expert, similarly stresses, "The whole point is that science must be brought to bear on the management of science itself."[5]

Accordingly, there has been a proliferation of science policy studies and "research on research" in the USSR during the last decade. Virtually the entire social science research sector has been put to work on the problems of acclerating S&T progress. The main purpose of such studies, Gvishiani notes, is to provide a strong "theoretical basis on which the fundamentals of science policy are worked out." Underlying the growth of the "science of science" movement is an intrinsic belief in and professed need "to study science as a controllable system and to attempt a more thorough exploration of the interrelationship of different aspects of this system with a view to increasing the efficiency with which it functions."[6]

In line with the basic Soviet approach to science and technology generally, the dominant emphasis in both theoretical study and practical policy has been on the need for a "systems approach." As Gennady Dobrov explains, "More than half a century of experience in the formulation and implementation of Soviet State science policy shows that one cannot expect to be consistently successful in science management if one pursues only one part of the system of goals."[7] Official Soviet claims to the contrary notwithstanding, the Kremlin still lacks comprehensive and coherent S&T policies. This is especially true in the civilian sector where capabilities for problem definition and systems management have been much more deficient than in the military and space areas. On both the theoretical and practical levels recent efforts point to the need and determination of Soviet leaders to develop a greater integrative capability, analytical and administrative, in order to apply more effectively a systems approach to S&T policy.

While there are still many loose ends and untreated questions in the literature, nonetheless the work of Soviet specialists in wrestling with complex S&T issues is impressive. A new sophistication is evident. More and more, new ideas and attitudes are beginning to penetrate and shape S&T thinking and policy making in the Kremlin.

Much of the debate on how to improve performance and to promote S&T progress has centered on six issues. One prominent set of concerns relates to the question of expanding the boundaries of science policy and of integrating science policy with economic policy. A second major theme is the need to move to an intensive growth strategy for science and technology with an emphasis on increasing the efficiency and effectiveness of R&D. The four remaining issues are essentially subsets of the latter problem. Taken together, they deal with ways of raising overall performance through greater organizational flexibility and institutional restructuring, improved planning and resource allocation, and more effective management and motivation throughout the research-to-production process. A common theme punctuating and dominating discussion in all these issues is the need to apply a systems approach to contemporary problem solving. The whole thrust and tone of the debate are in line with the intrinsically comprehensive and centralized approach of Kremlin decision makers. It is also not accidental that "linkage" and "integration" have become the key terms of the debate. They point clearly to the major interface difficulties and deficiencies that underlie such an approach in general and the Soviet R&D system in particular. Behind Soviet thought and action is the hope that "the holes in the whole" can be filled and more effective coupling can be achieved in the creation and application of new technology.

INTEGRATING SCIENCE POLICY AND ECONOMIC POLICY

An implicit feature of Soviet thought in the 1970s was the movement towards a broader concept of science policy and the closer integration of R&D with the totality of domestic and foreign policy. Traditionally, scientific R&D has been conceived apart from the wider political and economic context rather than as an organic part of it. In fact, science has often been viewed more as an appendage of social and cultural policy than as an aspect of economic policy. Increasingly, however, attention is being given to its status as a direct force of production and key source of economic growth in the era of the STR. The focus is on relating S&T to a much broader range of national aims and activities, on the role of R&D in solving contemporary economic and social problems.

In line with this more strategic approach is the emphasis on external rather than internal criteria in science policy. By the end of the 1960s Gvishiani had sounded the new line. He noted that R&D planning and management was no longer simply a question of the rational planning of science expenditures, of the training of scientific manpower, of the allocation of resources, or of the supply of scientific instruments. "The issue is broader and deeper," the deputy chairman of the GKNT affirmed,

> It is about the future, about the long-term development of socialist countries, about the very fate of the world and of socialism.

> For now only that system can win which is able to assure itself a vanguard position in scientific and technical progress.[8]

To phrase the issue somewhat differently, the object of planning has gradually shifted from primarily "new technology" to "scientific and technical progress" more broadly. Prior to the Eighth Five Year Plan (1966-1970), planning agencies operated with only the concept of new technology. The notion of technical progress was confined to theoretical social and economic literature. Brezhnev himself observed in 1971, however, that the demands of the times required a change of focus: "In an age when the role of science as a direct force of production keeps growing, separate scientific achievements, no matter how brilliant, are no longer the central issue. What is central," the General Secretary asserted, "is a high S&T level of production as a whole."[9]

However, there is no consensus in the Soviet Union regarding the definition of "new technology," "the technical development of production," or "scientific and technical progress."[10] To a large extent, disagreements about the meaning of "managing S&T progress" replicates the ongoing disputes about the general concept of "management." A semantic jungle exists in both spheres.[11] In essence, the issue is how to make the concept operational, how to designate the boundaries of S&T progress--its structure, content, and component elements--as an object of planning. Without a precise definition it is extremely hard to establish the place and role of the concept in the general system of economic planning and management.[12] Academician Fedorenko admits, in regard to the prolem of modeling technical progress and its economic, social, and ecological consequences, "we are only at the very beginning of complex and arduous research." Significantly, with the Tenth Five Year Plan a new subdivision on basic indicators of S&T progress was added to the plan for the development of science and technology. It represents the first attempt to define some basic technical and economic parameters characterizing the level of production and the manufacture of output. However, in the words of one high Gosplan official, the choice of appropriate indicators remains problematic, because "there is essentially no experience in this area."[13]

As Kremlin policy makers have focused less and less on R&D as a relatively isolated entity and more and more on the interplay of R&D with industry, official insistence grows that R&D and its applications be closely linked. The aim of policy cannot be solely the expansion of S&T per se or "science for science's sake" but must include its use as an instrument for economic growth and industrialization. "Relevance" has become a big issue, if not the fad of the day, as the Soviet leadership seeks greater and faster payoffs from the nation's substantial investment in scientific R&D. Indeed, a major challenge consists in formulating a science policy to promote innovation, to build an effective strategy of research utilization. In the early 1970s Brezhnev, in fact, singled out the application of R&D results as the most important but also the most deficient aspect of S&T policy. "If we examine all the links of the intricate chain that binds science to production, we shall easily see the weakest links are those relating to the practical realization of scientific achievements, to their adoption in mass production." It was necessary, the General Secretary stressed, "to create conditions compelling enterprises to manufacture the latest types of products, literally to chase after S&T novelties, and not to shy away from them, figuratively speaking, as the devil shies away from holy water."[14]

Despite the espoused need for more effective coupling, however, the integration of science policy and economic policy has been slow and difficult to achieve in practice. In May 1974 the Chairman of Gosplan still noted, "It is urgently necessary to shift from the planning of S&T potential, which is what the S&T plan is at present, to planning the mass production and diffusion of new technology."[15] Planning R&D remains geared to the creation of new technology and advances in science rather than to the application of existing knowledge and achievements. This causes one analyst to complain:

> The system of managing S&T progress is concentrated on the *means* for achieving goals and not on the *goals* themselves, for the sake of which new technology is being developed and introduced. Thus, the plan is drafted and accounting is conducted not according to the results of technical progress but only in terms of the means for achieving them.[16]

Research and production continue to coexist as largely autonomous worlds. "Basic economic activity" is still generally planned separately from "technical progress." The whole research-production cycle is not yet unified. Above all, views continue to differ over how to achieve the interfacing of science and industry.

SWITCHING TO AN INTENSIVE GROWTH STRATEGY FOR SCIENCE AND TECHNOLOGY

Another major theme of the 1970s was, to use Dobrov's words, "the shift in emphasis in national science policy from a quantitative to a qualitative approach."[17] Since 1955 the number of scientists in the USSR has doubled nearly every five years, growing six times faster than the country's total work force. Official expenditures on science have also expanded at the same rapid pace, climbing from 1.7 billion rubles in 1955 to 17.5 billion 20 years later. According to Soviet estimates, if these high growth rates are sustained, then by the year 2000 there will be approximately 21 million scientists and 85 million persons working in the general sphere of science and science services! Similarly, the share of allocations to R&D would consume 60 percent of the total national budget![18] This has given rise to the feeling, at least in some Moscow circles, that the saturation point has been reached and that limits need to be imposed on the growth of scientific manpower and expenditures.[19]

Alternatively, the need for greater productivity in the R&D sector has become increasingly apparent. As long as science and technology developed predominantly through extensive means--by exponential increases in the number of scientists, the size of budgets, the amount of equipment, the number of facilities, etc.--there was no particular need to analyze, much less improve, organizational structures and performance, observes G. N. Volkov. The switch to an intensive path of development, however, requires greater attention to the effective use of available S&T resources and achievements.[20] Under these modified conditions, a major aim of science policy, Dobrov notes, "is to ensure a rate of growth in the performance of science which keeps ahead of the high absolute rates of growth of resources and organizational parameters of scientific systems."[21]

Just as for broader economic policy, therefore, the question of rational resource allocation for science policy has become dominant. At the 1971 Party congress Premier Kosygin signaled explicitly the need for a general turn of course:

> Realization of the possibilities of the STR requires more and more expenditures. However, at each stage of its development the state has available only a fixed amount of resources that it can allocate for these purposes. Thus the need arises for choice and for the preferential development of the most important directions of S&T progress, for the formulation and implementation of a uniform national science policy.[22]

To dispel any lingering doubts about the continuing importance of this course, Brezhnev told the Twenty-Fifth Congress five years later, "Emphasis on efficiency--and this must be said again and again--is the most important component of our entire economic strategy. In the 1980s accomplishment of this task will become especially urgent."[23]

Under these conditions, problems of choice, priority, and policy have become increasingly important. In turn, they have fed the quest for relevance and the drive to weed out unpromising and unimportant lines of research. That much still remains to be done in this regard, however, is evident from Brezhnev's remarks to the presidents of the academies of sciences of several socialist states in February 1977, "But why not admit it," he said frankly. "The live and healthy tree of science sometimes has dry and even barren branches. It still happens sometimes that research is conducted in completely peripheral or even in simply fruitless directions."[24]

Unfortunately, there are no reliable statistics that show the impact of the government pressure for technology development and delivery on the actual structure of R&D expenditures. It appears, however, that the commitment to fundamental research remains firm and that there has been no significant shift of funds away from basic science. Indeed, the budget of the USSR Academy, the citadel of basic science, has reportedly grown faster in recent years than the national budget for R&D as a whole.[25]

These pressures for economy in R&D and for improving research utilization, in turn, have generated rising interest in cost effectiveness studies. An intense search is underway for criteria and ways by which to measure the return on investment in new technology. Opinions differ greatly and obstacles abound, however. A number of specialists caution against adhering too stringently to economic cost alone in assessing new technology. Some stress the need to take into account "social effectiveness," as expressed in improved social relations or better working conditions. Similarly, a few champion what is sometimes called "ecological" or "wasteless" technology, such as pollution control devices. Adopting yet a different view, others argue that "science is not a lottery with guaranteed prizes. Many lines of research produce no profits, or at least none measurable in terms of money." There are also some who emphasize that the magnitude of the socio-economic return depends not only on the result itself, but also on the speed and scale of its application. Many a good scientific idea or engineering solution quickly becomes obsolete.[26]

In addition to this diversity of opinion about the efficiency of technology, various procedures have been developed for calculating its effectiveness. Until recently, each ministry and state committee used its own method and set of indicators. Without uniform methodology, however, any comparative evaluation and choice among alternative S&T designs is impossible. Significantly in February 1977, a unified methodology for the calculation of the economic return of new technology, inventions, and efficiency proposals was made compulsory for all branches of the economy. The procedures contained in the methodology had been tested since 1971 in the unified fund ministries. However, in spite of the comprehensiveness of the methodology and the extensive preparation and experimentation behind it, the individual ministries are still required to devise instructions for adapting it to their own accounting practices and categories of output.[27]

In general, past procedures for measuring economic return have had major deficiencies. The anticipated effect has been systematically exaggerated, and the actual return is not properly considered or monitored. In fact, no statistics are kept in this regard. The system of incentives is also pegged to the calculated return. Not surprisingly, therefore, Lev Gatovsky, a prominent authority on the subject, confirms frankly, "Up to now the economic effectiveness of new technology has not been a leading principle in economic management or an object of planning."[28] V. S. Tarasovich and Yu. B. Kliuka add,

> Calculations of effectiveness, as a rule, are made only after basic work is completed, that is, when expenditures have already been made and time and resources are spent. Consequently, these calculations essentially are directed not to substantiating the expediency of conducting work but to the 'justification' of costs already incurred."[29]

At a national round table on S&T progress, held in Moscow in the fall of 1975, it was noted that the dominant engineering thought of the country remains: "I create technology and leave the effectiveness of production to others."[30] Thus, much remains to be done before substantial progress can be made in moving towards an intensive mode of growth and before an effective strategy for using S&T can be worked out.

ACHIEVING ORGANIZATIONAL FLEXIBILITY AND INSTITUTIONAL RESTRUCTURING

In seeking ways to improve effectiveness of R&D, Soviet analysts and policy makers have begun to think seriously, really for the first time, about Organization. Basic concepts related to organization and the structural requirements of technical progress are being reexamined and revised. A relatively static view of organizational structure as an immutable given is being replaced by a more dynamic conception of organization as a set of complex variables about which considerable choice can be exercised.

Organizational design itself is becoming recognized as a distinct and important area of expert analysis and management specialization. To be sure, there has long been a penchant for organizational engineering. Almost by reflex the remedy for any problem has been "to reorganize"--often without organization studies. Until recently, the political command simply did not see any need to do anything about organization, to think about organization, much less to think through to a new structure for science, technology, and production. In general, old managerial forms were mechanically carried over to new organizational structures without eliminating their deficiencies or examining their suitability under changed conditions and goals. To perform these tasks today, Boris Milner, the foremost Soviet authority on industrial design, insists, "trained organization specialists are needed, not reorganizers who are able only by intuition to put together new combinations from old administrative elements." Indicating there is political support for this view, Brezhnev has also emphasized the need for a more scientific approach to organization-building and administrative restructuring. Talking about these issues in Alma Ata in March 1974, he said, "We must act not by eye, not by intuition but be led by experience, experiments, and the conclusions of modern management science."[31]

Above all, a change of focus is called for. In the past those who worked on problems of structural design concentrated on current tasks. They dealt, as Milner puts it, "in statics, not in dynamics." Structures were interpreted predominantly as variations on a common theme, namely the division and evolution of line and staff functions. To quote Milner, structures were regarded "as a permanent collection of line and staff services, formed over a period of 30 years without showing any developmental tendencies or taking into account new tasks." "The basic focus," he adds, "was on the differentiation and specialization of functions, not on their integration and joint actions with respect to common goals."[32]

The "new school" of organization theorists, on the other hand, adopt a systems approach to structural design. They see structure not as an aggregate of universal functions carried out by separate and distinct agencies but as a means for achieving organizational goals. Goals are to be made the chief determinant of organizational structure and processes by which tasks are allocated and performance motivated, rewarded, and controlled. As Milner says, "Thus, in the beginning is the goal; then comes the mechanism for achieving it." The emphasis in designing structures must be on flexibility rather than permanence of relationships. "The task is to ensure dynamism, flexibility, and adaptability in systems of management," writes Milner. "The issue," he explains, "is about introducing organizational structures that are able to respond rapidly to changes in external technological and economic conditions, that can ensure long-range planning, improvement of production organization, a rise in product quality, better ties with consumers, study of product demand, efficient utilization of resources, and the organization of effective financial and credit relations."[33] As conventional organizational approaches have become ineffective in dealing with problems, the systems view has emerged as a way of coping with complexity and change.

On another level, there is enhanced awareness of a direct correlation between technology and structure. Technical progress and organizational development are seen increasingly as being interrelated and interdependent. Kalita and Mantsurov, for example, observe, "The level of organization and management of production to a significant--if not decisive--degree now predetermines the rates of S&T progress." They acknowledge "a direct dependence between organizational and technical factors of production, between the nature of its structure and the rates of technical advance." Milner also notes that qualitative changes in organization and management "are becoming a premise and a result of progress in science and technology."[34]

Accordingly, the adoption of a new strategy for technological innovation and development is seen by some to require organizational adaptation as well. As Brezhnev observed in 1971, the new demands on organization and management "do not allow us to be satisfied with existing forms and methods, even where they have served us well in the past." P. M. Masherov, a candidate member of the Politburo, told the Party congress in 1971, "Still not all of our executives fully understand that it is impossible to 'squeeze' the revolution in science and technology into the framework of old methods and organizational forms of work." Two specialists on innovation, P. Danilovtsev and Yu. Kanygin, similarly insist, "To attempt to put the research-production cycle into traditional forms of organization and management is like trying to use a steam-boiler to harness thermonuclear energy."[35] Experience has also demonstrated the difficulties of applying new methods of planning and management, including computer-based information and control systems, within established structures. More and more, then, there is movement toward the view, advanced by numerous Western writers, that "structure follows strategy," that organizational forms, to be effective and sound, must adapt to changes in technology strategy.

In the process of rethinking organization, some of the deficiencies of the pattern and consequences of structural evolution in R&D have become steadily apparent. As often happens with rapid growth, the burgeoning development of the Soviet S&T establishment, especially since the mid-1950s, has been a disorganizing and disorganized process. Little thought or analysis was given to organizational design and development. There was no conceptualization, measurement, or assessment of organizational effectiveness. Organizations simply "evolved," largely in an unplanned and unsystematic fashion. Today, as a result, even the names of some facilities bear little resemblance to their actual activity. Speaking about this pattern of growth, Mikulinsky writes,

> Old institutes gradually tend to spawn a great many diverse extensions and superstructures, swelling out into an agglomeration of numerous laboratories, departments, sectors and groups which frequently have no more than administrative or organizational links. As they grow, such institutes cease to be manageable, lose their character of being a definite creative collective, and this has a negative effect on the solution of major problems calling for concentrated efforts.[36]

Sheinin also notes that many R&D institutions "continue to exist largely by inertia, become preoccupied with far fetched or secondary problems, and avoid new directions and new questions, becoming ends in themselves."[37]

Two major organizational deficiencies in science and technology come in for particular criticism. The first is the relative rigidity and bureaucratic character of R&D institutions. E. I. Gavrilov faults these organizations for "their slow response to changing goals, tasks, and projects, their incapacity for extensive integration and cooperation, and their ineffectiveness in resolving scientific and production tasks." V. N. Arkhangelsky sees the main weaknesses of R&D structures as their "static quality" and "organizational exclusiveness." In the same vein, Mikulinsky writes, "New lines of research find it ever harder to find their place within the framework of established collectives and crystallized organizational forms." Gvishiani, too, speaks about science having "a surplus of stability and in some instances even of conservatism." One of the main demands being made on science, he stresses, "is that it should become much more flexible and mobile and capable of much easier and faster reorganization and even of total restructuring, when the need arises."[38]

At the same time, organizational change is recognized as being a formidabl task. Gvishiani himself admits, "It is extremely hard to recast the structure of a scientific establishment that has taken decades to shape." In practice, it is easier to create a new R&D facility than to transform an old one. This option, however, which has been frequently used, is less viable today given the constraints on resources and need for intensive development of both science and industry. Moreover, restructuring involves building organizations that are not only more fluid but also both flexible and stable. Yet finding the right blend of adaptability and stability is the "main difficulty" in the organization of Soviet S&T today, Gvishiani emphasizes.[39] The deputy chairman of the GKNT and others also acknowledge that the major problems in restructuring frequently revolve around the inability and unwillingness of scientists and engineers to switch from one field or project to another. The creation of large integrated research and production complexes requires a corresponding psychological remolding of collectives which are used to working in isolated groups.[40] In short, institutional restructuring involves considerable behavioral engineering and attitudinal change. The organizational issues, therefore, go beyond strictly structural and technical factors, a point that some--but not all--organizational reformers and "enthusiasts" realize.

The second major deficiency concerns the organizational dissociation of R&D participants and the severe coupling problems that this creates in moving ideas from the lab into use. The traditional approach to innovation, based upon extreme functional specialization by institutional performers, has left the process structurally fragmented and shapeless. Structural barriers have been created all along the innovation chain. In essence, the process has been unorganized and unmanaged.

To overcome this fragmentation, special emphasis is now being put on the need to apply a systems model of organization to innovation. Virtually every major writer on science policy in the 1970s, in fact, joined--if not led--the burgeoning systems movement in the USSR today. Because it focuses attention on interrelationships, interdependencies, and integration, the systems approach is regarded by many to be a viable conceptual framework for analyzing and solving structural design problems. Its emphasis on study of organization of the research-to-production cycle as a total system is new and underscores the emerging broader view of organizational structure as a means of facilitating decision making, motivation, and control. The application of a systems model transforms the innovation process allegedly into "a unified and self-regulating dynamic system." The research cycle becomes "a continuous and goal-directed process."[41] Recent organizational policy aims, then, at making the process both managed and manageable.

Practical manifestations of the systems approach to organization are seen in the variety of integrated structures and new associational forms linking research, development, and production activities that have arisen in recent years. Research and production complexes have indeed become a phenomenon of the times. Regional R&D centers, modeled somewhat after American research and industrial parks, have sprung up in a number of areas and join industry and educational institutions or academy institutes and experimental production facilities.

Wrestling with the problems of innovation, Kremlin authorities have become increasingly aware of the importance of linkage and of the need to structure more explicitly and effectively the vital interfaces in the transfer process. Accordingly, linkage is a prominent feature in the designing of new structures or modification of established arrangements. The search for more effective and flexible designs has also led to rising interest in project and matrix forms of organization and management. Indeed, the matrix model is seen by some analysts to be the ideal structure for R&D in the future. It is regarded as an effective way of institutionalizing flexibility and stability.[42] At present, however, matrix organization is still used on a limited and experimental basis in civilian R&D. Nonetheless, current organizational thought, at least in some prominent Soviet circles, points to an expansion of the matrix and of other shapes for R&D management in the 1980s.

In sum, a new and more sophisticated style of thinking about organization and the structural requirements of technical progress has recently developed in the USSR. New attitudes and approaches are emerging as the leadership begins to address some of the fundamental structural problems impeding S&T performance and capacity. Both foreign and domestic experience have convinced some segments of the ruling elite that "the management structure of economic organizations should be designed no less carefully than new technology," according to Georgy Arbatov, Director of the Institute for the Study of the USA and Canada.[43] Monolithic organizational perspectives are gradually giving way to multi-institutional views as the Kremlin seeks to cope more effectively with advancing technology and complexity.

To be sure, practice lags behind conceptual advances. V. A. Trapeznikov of the GKNT admits that in structuring and managing large complexes and organizational S&T systems "we are essentially only beginning work."[44] Organizational experimentation and structural change have been limited. Nonetheless, the leadership appears increasingly serious about helping make organization itself a positive force for, rather than impediment to, innovation. Given the heavy emphasis on organizational issues and approaches, in fact, the key to innovation seems, at times, to be simply "management by structure." In any case, it is important to note that the basic building blocks are beginning to assume new shapes. Integrated research and production complexes are coming into being. Organizational arrangements are being repatterned and authority lines recycled. The Soviet S&T establishment is in motion and in transition.

IMPROVING PLANNING AND RESOURCE ALLOCATION

There is also enhanced awareness of the complexity of planning and stimulating S&T progress. Some of the shortcomings and disincentives of the planning system with respect to innovation have become steadily apparent, as has also the need for greater initiative and user-stimulated innovation in R&D. "We cannot divide the 'plan-stimulation' formula into two parts and subordinate one to the other," some specialists argue. "We all realize," they add, "that it is impossible to solve the whole problem by moving just one lever alone."[45] Thus considerable attention was given in the last decade to strengthening the role of "economic mechanisms" (e.g., prices, credit, profitability) and of various incentive schemes in promoting scientific research, development, and delivery.

The dominant approach to S&T policy, however, remains fundamentally management-centered rather than entrepreneur- or market-centered. V. M. Ivanchenko, an official of the USSR Gosplan, expresses the prevailing view: "It is impossible to transfer problems pertaining to the acceleration of S&T progress to economic levers and stimuli alone." The predilection for central planning persists. The commitment to central planning remains firm. Indeed, it is said, "The management of technical progress needs to be centralized more than any other area of economic management." The national economic plan proper, concluded the recent round table of experts, "must be the main link that we must grip in order to pull the entire research-to-production chain."[46]

In the sphere of S&T planning, attention has focused largely on two needs: long-range forecasting and planning geared to the ultimate utilization of research results; and more integrated program-type planning and effective project control. To meet the first need, Soviet authorities have pressed the campaign to extend the horizons of planning beyond the prevailing short-term incremental mold in order to accommodate the kind of decision making and long lead times inherent in the development of science and technology. For all practical purposes, Soviet economic planning is an annual matter. The dominant tendency is to plan "from the achieved level." The expansion of existing production patterns prevails over the development and introduction of new products and processes based upon S&T. As a result the plan for S&T has remained largely "an appendage of the general economic plan, an independent chapter insufficiently integrated with the whole."[47]

Significantly, in 1971 Brezhnev stressed that a new approach was needed to make the macroeconomic plan a powerful lever of S&T progress, to ensure the rational management of both economic growth and new technology. He called for the formulation of a comprehensive program for the development of science and technology that could then be used as the basis upon which to build a 15 year general economic development plan. Such a program, he told the Party congress five years later, "provides points of reference and orientation without knowledge of which it is impossible to manage the economy successfully."[48]

Since 1973, in fact, work on such a general development plan that would extend to 1990 has been underway. Given the tremendous and recurring difficulties the leaders have in trying to devise even feasible five year plans, however, it is no wonder that such long-range planning has encountered stiff resistance and serious methodological obstacles. The Academy and the GKNT completed a partial draft of a "Comprehensive Program of S&T Progress and Its Social and Economic Consequences for 1976-1990" by the fall of 1975. Indicating that this effort did not yet meet with full approval, the Party Congress in February 1976 instructed the Academy and the State Committee "to continue" their work on this subject and "to see to it" that the forecasts "are better grounded."[49] Preparation of a general 15 year development plan for the country continues to encounter delays and difficulties.

Though we still know very little about the details of the Comprehensive Program for S&T, it is possible to glimpse from available information at least a few of the central concerns surrounding this endeavor. In general, the more than 150 forecasts prepared for various fields of science and technology before drawing up the Comprehensive Program were only partial forecasts. They focused on the development and production of only a few select products and processes. In addition, each forecast was developed predominantly on a branch basis, separate from the rest in material and labor resources. The lack of a "systems approach" to planning and resource allocation admittedly diminishes the value of the forecasts.[50]

Particularly significant, the major projects included in the Comprehensive Program are based only upon S&T achievements that have already found practical application. "This reduces, of course, the possibilities for technical progress posed in the Comprehensive Program but, at the same time, makes the general targets and indicators realistic and reliable," claims a study produced by the Higher Party School under the CPSU Central Committee.[51] Nonetheless, there are some, like A. S. Gusarov of the Academy's Institute of Economics, who disagrees with this approach to planning, uncertainty, and risk. He emphasized at the 1975 round table, "After all, we must be concerned not only with mastering the experience that has been amassed in the course of S&T progress, but also with mastering the ongoing revolution in science and technology." Gusarov and others apparently fear that this conservative approach to building the future entirely on the accomplishments of today, no matter how high, will only lead to "planned obsolescence." As a recent major Soviet work on science policy put it, such planning amounts essentially to "programming backwardness, not progress."[52] It also does not constitute a viable strategy for closing the technology gap with the West. On the contrary, it carries the possible danger that the USSR will fall even further behind. As Gusarov observes, "After all, it is possible to lag even while moving forward."[53]

To meet the second need, continuing emphasis has been placed on broadening the application of a "programmed-goals approach" to planning and management. A kind of "programmitis" has gripped the Kremlin as many have fastened on this management-integrative tool with high hopes of solving the mounting problems of complexity and change. Its use is being urged for major construction projects, like the territorial-production complexes being built in Siberia, Central Asia, and the Far East, as well as for large-scale R&D programs. Calling for comprehensive programs centering on key scientific, engineering, economic, and social problems, Premier Kosygin at the 1976 Party congress singled out as priority tasks the development of the nuclear power industry and the mechanization of manual and heavy physical labor. A. P. Aleksandrov, President of the Academy of Sciences, suggested that the modernization of agriculture and development of computer technology be raised to this special national program status. Brezhnev, on the other hand, stressed to the congress the importance of formulating comprehensive programs for the development of the fuel and power complex, metallurgy, and the leading branches of machine building.

As regards science policy specifically, movement towards programmed-goals planning is most evident in the switch from "coordination plans" to "integrated programs" for high priority S&T problems. The number of basic problems has also been reduced to around 200. Much more than before, the accent is on the actual introduction of R&D results into the economy, on integrating science, technology, and production. This follows Brezhnev's own stress at the 1976 congress on the need to focus planning and management more on "end results." "This approach becomes especially urgent," he explained, "as the economy grows and becomes more complex, when these end results come to depend more and more on a multitude of intermediate units, on an intricate system of intrabranch and interbranch ties." "In these conditions," Brezhnev insisted, "It is easy to overlook the most important thing--the end results."[54] Scientific R&D has in particular frequently been caught in "the activity trap," when activities become an end in themselves and their end results are lost to sight. As we have noted, even the coordination plans for priority S&T problems have tended to end with the experimental design and testing stage and, in exceptional cases, with the production of prototypes. For all practical purposes, the planning process has stopped short of series production. Scientific R&D thus has failed to produce substantial practical results, to follow through to industrial assimilation. Suffice it to note that another important aim of the new integrated S&T programs is to facilitate more effective coordination of R&D plans with investment plans and with the allocation of material and technical resources. Thus, the change in planning involves more detailed control and managerial surveillance, not just the introduction of R&D results.

Underlying this heavy accent on the systems approach to planning is the need to deal more effectively with major interbranch problems that cut across ministerial lines. Brezhnev particularly complained to the 1976 congress about too many "nursemaids," about the fragmentation of decision making and administration, leading to unwarranted cost overruns and protracted delays. "What is required here," he told the congress, "are integrated and centralized programs embracing all stages of work, from project design to practical implementation." Lending his support to the systems movement, the General Secretary charged that "the question of improving the methods of solving major interbranch and territorial problems of state importance cannot be put off."[55] M. P. Ring, a prominent science policy expert, also emphasizes that the Soviet government cannot continue to solve major complex S&T problems incrementally "by pieces," and by means of territorial and branch planning alone. Such a policy leads to "slow, incomplete, and insufficient solutions."[56]

It is important to mention again that, despite the long tradition of central economic planning, Soviet authorities have lacked until relatively recently the necessary organization, techniques, authority, and experience to plan and manage R&D on a comprehensive level. This is particularly true for the civilian sector with the exception of a few crash development and high priority programs, like chemical technology or atomic energy. Planning of R&D has been--and still predominantly is--conducted on an institutional basis. Given the extreme functional specialization of institutional performers and the structural fragmentation of the innovation process, it has not been possible to plan and manage projects within the framework of one or two organizations. A major aim of the drive to create large research and production complexes is to build an organizational basis for broader program planning. Such structures permit the development and use of more sophisticated techniques of systems management and project control.

Thus, systems planning and programming is seen by many to offer a remedy--if not a panacea--by which to overcome existing deficiencies. But experience remains limited in this area. As Academician T. S. Khachaturov, editor-in-chief of the main Soviet economic journal, cautioned the 1975 round table on S&T progress, "This is indeed an enticing prospect, but to what degree has the ground been laid for program-integrated planning?" Indeed he reminded them, "It is appropriate to remember that work is only now beginning on questions pertaining to planning based on complexes and programs."[57] There are still many unresolved issues not only about programming *per se* but also about how to fit programming techniques into the general system of Soviet planning. The issues here are far from purely methodological.

RAISING MANAGEMENT EFFECTIVENESS

Problems of choice, priority, and policy are, above all, management problems. Indeed it is possible to say that management has emerged as the "central issue" in Soviet science policy and development strategy today. A. V. Sobrovin of Moscow University expresses the prevailing official view: "The problem of technical progress is first and foremost a question of management."[58] In June 1970 Brezhnev observed, "The solution to many of our economic problems should now be sought at the junctures between progress in science and technology and progress in management."[59] Gvishiani writes similarly:

> It is no exaggeration to say that the pace of our advance hinges on organization and capabilities in the system of management. Fusion of the latest achievements in science and technology with the most up-to-date achievements in organization and management is an imperative of the contemporary STR.[60]

Growing appreciation of the critical role of management, in turn, has brought enhanced awareness of the need for more effective R&D administration. Sobrovin says frankly, "Let us build a modern system of management of technical progress. If we do not do this, we will accomplish nothing."[61] Stating what has since become a slogan of the times, Brezhnev declared in June 1970 that "the science of victory in building communism is in essence the science of management."[62] The linchpins of his grand strategy have become the "management of science" and the "science of management."

A critical "management gap" therefore is an integral part of the perceived "technology gap" in the USSR. Soviet authorities have come to recognize more and more that the existing technology of management is increasingly inadequate in coping with modern R&D problems. Innovations in planning, organizing, and controlling activities have lagged along with advances in technological hardware. There exists a new level of awareness of the need to develop and to apply modern decision-making techniques and management attitudes toward S&T policy. Indeed underlying these concerns, it seems, is the idea that perhaps the fastest and most effective means of overcoming Russia's technological backwardness in modern hardware is through a great leap forward in "software" and management know-how.

Again, as in organization and planning, the major problems in management lie in the fragmentation of R&D decision making and administration. This results in poor direction and integration of effort--the heart of management functions. Integrative capabilities are, moreover, becoming increasingly important in S&T policy. "The problem of ensuring *continuity* of the process at every stage of R&D, including the introduction of results into mass production," writes Gvishiani, "is now being brought to the fore as the most complex organizational task. It is absolutely obvious that this process requires integrated management." Professor G. Kh. Popov, Dean of the Economics

Faculty at Moscow University, also notes, "Today virtually all questions of any importance--and above all the key problems of S&T progress--have become interbranch in nature." "This is why," he explains, "improvement of the mechanism of interbranch coordination is one of the core problems of management." As regards this problem, Politburo member M. S. Solomentsev, who is also Premier of the Russian Republic, acknowledges flatly, "There is nothing of greater urgency."[63] Indeed, the administrative machinery encounters its greatest challenges in dealing with complex S&T problems. At a time when the importance of this class of management problems is rising, the deficiencies of the existing system of coordination are becoming all the more apparent.

Official concern with surmounting these shortcomings provides, in fact, the impetus behind the growing systems movement in the Soviet Union today. Systems technology is fast becoming the final word in organization, planning, and management as the leadership seeks more effective methods of integration and control.

Taken together, developments in the areas of organization, planning, and management indicate, to a large extent, the efforts being made to bring space-age management perspective and technique to the Kremlin. The current emphasis on setting objectives, developing action plans, determining the means to accomplish them, and appraising performance on the basis of results is the essence of modern management. The "programmed-goals approach" is basically Soviet-style "management by objectives," "results management," and "systems planning, programming, and budgeting," to use equivalent Western terms. Much like leaders of complex organizations the world over today, in government and business, Brezhnev and company are attempting to use these tools to improve managerial performance and effectiveness as well as to ensure Party control.

In the organization of management, two problems in particular are being singled out. The first is the need *to separate strategic and coordinating functions from operating management and control*. The failure of existing management structures to incorporate and maintain this division of tasks has caused them "to freeze the development of technology and the efficiency of production," writes Milner. In practice, both strategic and operational functions are concentrated at the highest levels of management. Consequently, the command channels become overloaded as problems are constantly referred upward. Top executives become absorbed in current operations and diverted from strategic concerns.[64]

Second, there is need *to formalize and expand horizontal patterns of management as well as to combine vertical and horizontal channels of administration.* Integration can take place only at the apex of the organizational pyramid. Thus, top management becomes heavily involved in securing horizontal joint actions and coordinating goal achievement by various functional units at lower levels. Again the result is the overload described above and the failure of organizational leaders to conduct strategic planning and decision making for the future. At the same time, the number of complex problems demanding team work and joint effort is growing daily. Numerous attempts have been made at plants and associations to create special bodies responsible for coordinating and harmonizing lateral ties at all levels of management. However, they have proven to be ineffective, Milner points out, "because they try basically to adapt the line and staff structure to solve tasks for which it is not suitable." Such problems can be solved most effectively, he adds, "within the framework of a special structure, one that cooperates with a line and staff structure, supplements it but is not identical to it."[65]

Basically, the Soviet structural response to these needs has followed closely the pattern of organizational and managerial adaptation in the United States. During the 1960s many American business firms found that well-known and well-tested structural designs and management shapes were inadequate in coping with complex problems of advancing technology. They faced many of the same pressures and design problems that preoccupy the Kremlin today. Similarly, interest in the design of strategic planning systems mushroomed as ways were sought to free top executives from operational worries. Differentiation and integration concepts were applied to structural design to achieve greater organizational flexibility and management effectiveness. Additional managerial roles were created to provide horizontal coordination across functional lines and vertical flows of authority. Among the most important structural innovations to emerge out of the 1960s were project management and matrix organization.

Significantly, these same two concepts lay at the basis of Soviet structural refinements and managerial reforms in the 1970s. According to Milner, they provide for "a flexible and dynamic system of interfunctional coordination and subordination of diverse efforts of individual links for accomplishing set objectives."[66] "Project teams overcome intraorganizational barriers and therefore avoid the basic contradictions of a functional structure," writes Taksir.[67] N. E. Drogichinsky notes, "In the matrix structure are optimally combined vertical and horizontal flows of leadership, the management of current production and scientific research, the development of new technology and retooling for manufacturing new products without violating the rhythm of production."[68] The main advantage of matrix organization, Gavrilov explains, is that it makes possible the transfer of operational management to lower levels and thus permits top management to step out of day-to-day decision making and to concentrate on strategy development.[69]

Accordingly, the concepts of project and matrix management are beginning to find application in the development and introduction of new technology in the civilian sector. Science-production associations in particular have become crucibles for experimentation

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with these new management modes. These design concepts are also being applied at higher levels of the administrative structure as part of the process of ministerial restructuring. The radio, chemical, and electrical engineering industries are on the frontier of experimentation in this area.

Nonetheless, it is difficult at present to assess the impact and future of these changes. Detailed information is lacking about the actual practice of project and matrix management. Evidence suggests, however, that these organizational innovations are not easily or rapidly assimilated. They challenge the way organizations are structured and the way people are managed.[70] The conversion to matrix management and more sophisticated administrative arrangements will necessarily be slow and difficult, as has also been the transition to new management forms in the United States.

Finally, it is important to mention the growing recognition in the Soviet Union of the need to make R&D management a distinct and separate form of managerial action and specialization. In the past innovation was not made a managerial responsibility. Both the researcher and manager have been characterized by non-innovative role definitions. The introduction of new technology fell entirely outside the normal duties of enterprise executives and workers. Management was geared to repetitive and unchanging production operations.[71] To accommodate a more rapid rate of technological growth, however, Prof. Popov and others argue that a new kind of management is needed that is oriented to innovation. The management of R&D must be developed and included as an integral part of the system of managing the enterprise, the branch, and the economy as a whole. In addition, this new managerial function must be put on a par with the management of production, of finance, and of supply.[72] More and more, then, Soviet specialists appear to be coming around to the view shared by numerous American analysts that innovation cannot be a subordinate and part-time task. The problems are too obstinate to yield to only occasional attention and half-hearted action.

STRENGTHENING THE BONDS OF MOTIVATION

The motivational and collaborative issues left unattended by previous approaches to innovation are also receiving greater attention today. On one level, efforts have been made to strengthen the role of economic stimuli. Some specialists feel, in fact, that too much emphasis is being placed on this direction. According to Gusarov, "Essentially the system of stimulation has been reduced to a system of material incentives, and this is not correct." Others argue, "We must not fear the creation of large incentive funds at enterprises producing high quality products: they pay for themselves entirely by eliminating losses due to low quality production."[73] New incentive funds have been established at R&D organizations, and steps have been taken to tie the funding and awarding of bonuses more closely to the return that R&D results yield the consumer and the economy. A number of experiments are also underway that seek to relate salary levels to productivity and to the results of work of research personnel.

In general, though, there remain a number of troublesome and unresolved issues surrounding this whole question. Yu. V. Borozdin notes, "The fact of the matter is that to date there is still a certain gap between the system of planning, the system of incentives, and the system of price formation." The awarding of incentives is based upon faulty and obsolete (1968) methods of pricing new products and of equally ineffective and outdated (1961) methods of determining economic return on new technology. Two systems of incentives still exist at production enterprises: one is geared to the fulfillment of basic economic activity and the other to the application of new technology. Not only do the two frequently contradict each other, but the latter system, according to M. I. Volkov, "is easily overshadowed" by the former. Lev Gatovsky similarly writes that the stimuli for new technology cannot serve as a real "counterweight" to the rewards for basic production. "Methods of cost accounting, the evaluation of economic activity, and the system of material incentives are too little oriented toward national economic effectiveness based on S&T progress," he affirms.[74] Despite the strong accent since the late 1960s on the importance of accelerating innovation, in fact, the *relative* share of incentive funds for applying new technology compared to the bonuses for fulfilling basic production targets has actually *declined* over the years.[75] Writing in the Academy's economic journal in May 1977, Gatovsky asserts that the innovating enterprise still finds that it does not occupy an advantageous and privileged position. On the contrary, this is still held by enterprises producing old and obsolete technology.[76]

In addition, the development of a unified incentive structure has been a special problem at all levels of the administrative hierarchy. Just as in R&D planning and management generally, divided authority and fragmented administration have been the rule in this sphere as well. Only recently have a few ministries switched to a system of unified funds for planning and stimulating the research-to-production process within the branch as a whole. Only in 1976 were guidelines laid down for the science-production associations on the formation and utilization of unified incentive funds. Previously, the central management or head organization of the NPO lacked authority to redistribute assets, investments, and funds of the constituent units. Each subdivision formed and spent its own fund for material incentives, and the NPO did not have any right to these funds. As a result top management could not utilize these resources or part of them as an economic instrument. The absence of unified funds and uniform rates for bonuses has prevented NPOs from using monetary incentives to encourage association members to pull in the same direction. A similar problem exists with respect to the use of incentives across ministerial lines to stimulate interbranch R&D. Scientific R&D organizations receive deductions for their material incentives fund from profits of individual enterprises only in their own branch. This dampens their interest in doing work of an interbranch character. At present there are no procedures that permit an easy transfer of bonus and wage funds, capital investments, and material resources from one branch to another to stimulate organizations, regardless of their departmental affiliation.[77]

On another level, strong emphasis has been placed on strengthening motivational bonds through the creation of a unifying goals framework. This tendency to view questions pertaining to incentives through the prism of the plan is in keeping with the basic centralized approach to S&T policy. Because the research-to-production process has basically lacked an integrating goals structure, the focus has not been on final results and overall integration but on separate functions and individual work efforts performed in isolation from one another. Coupling has been loose and disjointed. Individual and institutional participants are not fully aware that they are involved in a connected process. The whole activity chain moves through different links without the integrating force of common purpose and sense of teamwork.

Through more explicit use of a goals-oriented science policy and purposive technological innovation, the leadership is trying to build a more effective framework for cooperation and interorganizational collaboration. The accent on objectives and end results in programmed-goals planning and systems management approaches currently in vogue is designed to help build commitment and common purpose that can fuse structure and people in joint action. Through research and production complexes and associations the authorities hope to reshape the attitudes of R&D personnel and to create a coincidence of interest among all participants in the smooth and rapid transfer of technology. Instead of being guided by its own special interests and parochial views, each unit is to be motivated by common objectives, by "only one concept: ours." The new complexes are seen as means by which to transform "awkward external cooperation into harmonious intrafirm cooperation."[78] Such integrating structures are expected to build a more appropriate climate for innovation and to help get needed team play. Indeed, the Russian term most frequently used to describe these complexes and associations--obedineniye--comes from the verb "to unite" or "to join." It captures the explicit design emphasis on integration and cooperation.

To be sure, efforts are being made on a variety of fronts to strengthen motivational bonds all along the research-to-production cycle. Current approaches focus almost entirely on the creation of positive incentives to promote and reward innovation. Little attention, much less emphasis, is being given to the creation and use of negative incentives or sanctions that punish non-innovative behavior, such as are provided by a competitive market economy. In general, though, motivational bonds are difficult to assess until there is greater knowledge and understanding of the nature of anti-innovation attitudes and resistance to new technology in the Soviet Union. Indeed, this point was made by Sobrovin at the 1975 national round table on S&T progress: "We still do not know the reasons for the slow introduction of S&T advances by enterprises, and hence we do not know the objective base for searching for new forms and methods of stimulation."[79]

SCIENCE POLICY REFORMS: A BALANCE SHEET

Following Soviet S&T policies over the last decade, one is struck by a number of features. First, the growing sophistication of research and analysis in this area is amply evident. Important steps are being taken to advance understanding as a first step toward improving the practice of scientific R&D. The proliferation of "research on research" has led to greater awareness of the multiplicity of factors involved in moving ideas from the laboratory into use, along with greater appreciation of the importance of effective coupling throughout the process. Nonetheless, understanding of the innovation cycle remains incomplete. Many questions still lack adequate answers; some important issues have not yet even been raised in the literature.

At the same time, practice continues to lag appreciably behind perception. Just as in modern technological hardware, so also in modern software the implementation and diffusion of innovations in R&D planning and management remains a critical problem. Indeed, the ongoing science policy debate is replete with complaints that progress in introducing reforms is slow. Brezhnev observed at the 1976 congress,"The improvement of planning, the restructuring of the economic mechanism, and the policy of intensifying production proceeded slower than planned." He particularly lamented, "Despite the fact that this question was raised repeatedly and insistently, the application of S&T achievements is still a bottleneck in many branches."[80] Even more outspoken is L. A. Vaag of the State Committee for Science and Technology, who told the national round table on S&T progress in the fall of 1975, "Five years have passed and there have been no major changes."[81]

Though the Kremlin's new strategy for science and technology stresses the need for a total systems outlook and approach to remedy the problems of incomplete planning and disjointed administration of R&D, reforms themselves have been adopted in a piecemeal, experimental, and incremental fashion. Despite some steady gains made in the 1970s, a great gap persists between the aspirations of Soviet authorities for comprehensive and coherent S&T policies and their abilities to implement these wishes. In short, the Kremlin's reach still exceeds its grasp in this policy sphere.

The two systems for guiding S&T progress still prevail, and opinions continue to differ over how to improve and how to integrate them. The basic system of economic planning and management is oriented toward the expansion of production and today's technology, while the supplementary system is concerned with the planning and management of R&D toward the technology of tomorrow. For the most part, the target of attention and action has been the supplementary system. This prompts Vaag to exclaim, "We must think of improvements in the basic system and must not confine ourselves to improving supplementary systems for the stimulation of S&T progress."[82]

At issue is largely the role and future of the supplementary system. On one side are those who question the need to improve and to preserve this secondary line of influence. For them the central issue is making the basic system work for science and technology. If the economy as a whole is not altered to inspire and promote technological innovation, then improvements in the supplementary system, no matter what, will be of no avail. If the fundamental workings of the economy can be so modified, then a supplementary set of S&T mechanisms will be unnecessary. On the other side, there are some who focus almost exclusively on improving the latter machinery. They tend to inflate its role in and potential for accelerating S&T progress while downplaying the need for general system reorientation and change.

A middle position on this issue is held by Professor Popov of Moscow University. His views also probably represent the majority opinion among the Soviet ruling group at this time. Given the complexity of science and technology under modern conditions, Popov contends that it is necessary to retain, even in the future, two channels of influence. In describing the specific task of the supplementary system, he draws an analogy with modern aviation. Just as some advanced aircraft require an initial booster engine in order to accelerate to a certain level before the main engines cut in and take over flight control, so a modern economy needs a supplementary booster support system for the development and acceleration of science and technology. This secondary system of special mechanisms for R&D planning and management can fulfill its role only when it is closely integrated with and subordinated to the basic links of economic management. "It is impossible for this supplementary system alone to solve all the problems of managing S&T progress," Popov emphasizes.[83]

While everyone generally agrees that both the basic system and the supplementary system need to be improved, there is considerable dispute about what to improve and how. According to Popov, it is possible to identify three main schools of reform. One group focuses on improvements in planning, the search for better indicators, more sophisticated analytical techniques, etc. A second favors structural approaches and organizational solutions. A third school emphasizes the importance of improved economic mechanisms, such as more effective material incentives, better pricing policies, integrated financing, etc. The "best" policy, in Popov's opinion, is to pursue improvements along all three avenues, to unite all links of the supplementary system, and to integrate this system with the basic economic mechanism. Indeed, this multi-dimensional approach has been generally the path of reform in recent years.

On a broader level, developments in the 1970s confirm that in the Soviet Union, as elsewhere, the formulation and implementation of science policies depend not only on their substantive effectiveness but on their political feasibility as well. Suffice it to say that substantial disagreement persists within the leadership about the intensity of the "technological imperative." Opinions differ over the urgency of making the transition to more intensive growth in general and more rapid technological advance in particular. Political differences and conflict among the major elite groups constrain action in this policy sphere. Indeed it is politics that accounts largely for the basic discrepancy between the espoused strategy for S&T with its emphasis on the need for a systems perspective and approach to problem-solving and the tactics of implementation which recognize the need for a cautious, experimental, and incremental mode of reform.

At the same time, it is inaccurate to attribute the slow pace of science policy reform simply or solely to bureaucratic resistance and political conservatism, The responses of Soviet leaders to the manifold problems at hand appear to be based on a more complex calculus of decision. Not only do they recognize some of the fundamental--and not just political--constraints at work in the Soviet system. They also are more aware of the complexities of modern science, technology, and development. To be sure, some still cling to the hope of simplistic solutions. But solutions to complex problems are themselves usually complex. While this is not always understood, some Soviet specialists and political leaders are fully aware of the difficulties of effecting organizational and behavioral change. Milner himself articulates well the basic dilemma that confronts Soviet policy makers in science and technology as the USSR moves into the 1980s. There is no doubt, he says, that modern systems approaches and more sophisticated techniques make R&D planning and management more difficult. They bring it "into a new class, into a new situation." "But it is not possible by any other way," he emphasizes, "to solve the new and complex problems of development of the national economy, which have no precedent in our past experience."[84] Perhaps the greatest stride in contemporary Soviet S&T policy has been the discovery that there are no simple or final answers to the problems of advancing technology and change.

FOOTNOTES

1. See Andrei Sakharov, Roy Medvedev, and V. F. Turchin, "Letter of Appeal of Soviet Scientists to Party and Government Leaders of the USSR," March 19, 1970, reprinted in Survey, No. 76 (Summer 1970), pp. 161-170.

2. XXIV S"yezd KPSS: Stenograficheskii otchet (Moscow: Politizdat, 1971), I, p. 82 and XXV S"yezd KPSS: Stenograficheskii otchet (Moscow: Politizdat, 1976), II, p. 237.

3. L. I. Brezhnev, Ob osnovnykh voprosakh ekonomicheskoy politiki KPSS na sovremennom etape: Rechi i doklady (Moscow: Politizdat, 1975), I, p. 418; XXIV S"yezd KPSS, I, p. 80; XXV S"yezd KPSS, II, p. 24.

4. XXV S"yezd KPSS, I, p. 73.

5. V. A. Trapeznikov, "Upravleniye naukoy kak organizatsionnoy sistemoy," in Gvishiani et al, eds., Osnovnyye printsipy i obshchiye problemy upravleniya naukoy (Moscow: Nauka, 1973), p. 39; Gvishiani, "The Scientific and Technological Revolution and Scientific Problems," Social Sciences, I (1972), p. 49; Vladislav Kelle and Semyon Mikulinsky, "Sociology of Science," ibid., 3 (1977), p. 86.

6. Gvishiani, "The Scientific and Technological Revolution and Scientific Problems," p. 48; Gennady M. Dobrov, "Science Policy and Assessment in the Soviet Union," International Social Science Journal, XXV, 3 (1973), p. 322.

7. Ibid., p. 318.

8. Quoted in L. V. Golovanov, "Sistema upravleniya naukoy v SSSR i voprosy ee sovershenstvovaniya," in Nauchnoye upravleniye obshchestvom (Moscow: Mysl', 1969), III, p. 35.

9. *XXIV S"yezd KPSS*, I, p. 80.

10. See K. Yefimov, "Nauchno-tekhnicheskiy progress: organizatsiya i planirovaniye," *Voprosy ekonomiki*, 12 (1974), pp. 22-23; A. A. Podoprigora, *Pravovyye voprosy sozdaniya i vnedreniya novoy tekhniki* (Kiev, 1975), pp. 14-32; O. I. Volkov, *Planovoye upravleniye nauchno-tekhnicheskim progressom* (Moscow: Nauka, 1975), pp. 12-16; V. D. Volkova, *Sovershenstvovaniye metodologii planirovaniya nauchno-tekhnicheskogo progressa v usloviyakh razvitogo sotsialisticheskogo obshchestva* (Sverdlovsk, 1975), pp. 6-9; V. I. Pavlyuchenko, *Ekonomicheskiye problemy upravleniya nauchno-tekhnicheskim progressom* (Moscow: Nauka, 1973), pp. 9-37.

11. Yu. M. Sheinin, "Osnovnyye ponyatiya organizatsii i upravleniya nauchnoy deyatel'nostyu," in *Upravleniye, planirovaniye i organizatsiya nauchnykh i tekhnicheskikh issledovaniy* (Moscow: VINITI, 1970), II, p. 178; M. I. Piskotin, V. A. Rassudovskiy, and M. P. Ring, eds., *Organizatsionno-pravovyye voprosy rukovodstva naukoy v SSSR* (Moscow: Nauka, 1973), p. 31.

12. See M. A. Vilenskiy, "Nauchno-tekhnicheskiy progress kak ob"yekt planirovaniya (voprosy metodologii)," *Voprosy ekonomiki*, 12 (1973), pp. 71-81; S. M. Yampolskiy, "Ekonomicheskiye granitsy proizvodstva i primeniye novoy tekhniki pri sotsializme," in L. M. Gatovskiy, ed., *Ekonomicheskiye problemy nauchno-tekhnicheskoy revolyutsii pri sotsializme* (Moscow: Ekonomika, 1975), pp. 128-137.

13. N. P. Fedorenko, "Urgent Tasks of Economic Science," *Ekonomicheskaya gazeta*, 21 (May 1976), p. 10; Yefimov, "Nauchno-tekhnicheskiy progress: organizatsiya i planirovaniye," p. 26.

14. *XXIV S"yezd KPSS*, I, pp. 80-81.

15. *Trud*, May 23, 1974. See also Yefimov, "Nauchno-tekhnicheskiy progress: organizatsiya i planirovaniya," p. 24.

16. Volkov, Planovoye upravleniye nauchno-tekhnicheskim progressom, pp. 17, 19. Emphasis added.

17. Dobrov, "Science Policy and Assessment in the Soviet Union," p. 308.

18. L. Blyakhman commented on the increasing number of scientists in Neva, 1 (January 1973), pp. 173-181. See also K. L. Gorfan, N. I. Komkov, and L. E. Mindeli, Planirovaniye i upravleniye nauchnymi issledovaniyami (Moscow: Nauka, 1971), p. 8. For the budgetary projections, see E. Kosov, "Ekonomicheskiye problemy upravleniya nauchno-tekhnicheskim progressom," Ekonomicheskiye nauki, 7 (1971), p. 51.

19. See S. Mikulinskiy, "Problema nauchnykh kadrov v usloviyakh nauchno-tekhnicheskoy revolyutsii," Kommunist, 5 (1973), pp. 76-88; Zavlin et al, Trud v sfere nauki (Moscow, 1973), pp. 123-124.

20. G. N. Volkov, Sotsiologiya nauki: Sotsiologicheskiye ocherki nauchno-tekhnicheskoy deyatel'nosti (Moscow: Politizdat, 1968), p. 216.

21.Dobrov, "Science Policy and Assessment in the Soviet Union," p. 309.

22. XXIV S"yezd KPSS, II, p. 19.

23. XXV S"yezd KPSS, I, p. 67.

24. Pravda, February 19, 1977.

25. Statement by E. I. Sklyarov of the State Committee for Science and Technology as reported by Loren Graham in his "The Place of the Academy of Sciences System in the Overall Organization of Soviet Science," in Thomas and Kruse-Vaucienne, op. cit., p. 55.

26. See M. A. Vilenskiy, "Sotsial'no-ekonomicheskaya effektivnost' nauchno-tekhnicheskogo progressa," in Gatovskiy, Ekonomicheskiye problemy nauchno-tekhnicheskoy revolyutsii pri sotsializme, pp. 138-146;

V. Yu. Budavey and M. I. Panova, *Ekonomicheskiye problemy tekhnicheskogo progressa* (Moscow: Mysl', 1974), p. 26. Statement about the lack of profit in research made by Alexander Birman, cited in *Science and Public Policy*, III, 4 (August 1976), p. 367.

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XII A COMPARISON OF SCIENCE POLICY
IN THE US AND USSR

THE SCIENCE POLICY ENVIRONMENT

In science and technology the United States and the Soviet Union are truly superpowers. The massive scientific and engineering enterprises in motion today in the two nations together account for roughly two-thirds of the world's scientific research and development. Both countries have recognized that science and technology play an important role in the improvement of the human condition in their own societies and in the world as a whole. Both countries have recognized that science and technology are fundamental to their security; and, further, that the foundation for S&T advancement lies in a strong educational system for training scientists and engineers.

In addition to sharing a strong S&T orientation, the US and USSR exhibit striking similarities in the evolution of their science policies. In both nations R&D has burgeoned after World War II. Each has built within the last three decades an elaborate network of government agencies and special mechanisms to attend to the problems and consequences of scientific and technological advance. Despite different operating conditions and organizational approaches, both countries determine science policy at the apex of the governmental structure. In the US the states participate in S&T activities in only a minor role. They are neither significant performers nor significant sponsors of R&D, though the states do perform a vital role in funding and maintaining the educational system. In the Soviet Union the republics are more directly in the line of command of the S&T process. Forming the second level of territorial responsibility and authority for major segments of the R&D effort, the republics act as a conduit and interpreter of S&T policy and directives of central bodies. Given the highly centralized Soviet system and its distinct set of R&D priorities, however, republic and local involvement in science planning and management remains substantially circumscribed. With the exception of Georgia there are no counterparts to the USSR State Committee for Science and Technology on the republic level. "All-union," rather than "union-republic," much less "republic," ministries and agencies shape S&T policy and direct the national R&D effort, just as they do in economic policy and development more generally.

On the whole, both countries have made inordinately high investments in defense, aerospace, and nuclear R&D while underinvesting in technology for economic growth. Though technological innovation has certainly been a more prominent and widespread feature of the American economy than of the Soviet, still 80 percent of all US R&D has been concentrated in just five "intensively engineered" industries. Furthermore, 80 percent of federally supported R&D goes to just two of these sectors--aircraft and missiles, and electrical equipment and communications.

In both nations, scientific R&D remains highly concentrated geographically in a few major urban centers and is performed by a few large institutions. The Soviet penchant for large-scale organization and functional specialization is well known. Traditionally, head research institutes and design bureaus have been given primary responsibility for developing the main thrusts in science and technology. They are organized to serve whole branches of industry rather than individual production facilities. The small business firm and individual entrepreneur do play an important role in American science and technology, especially in innovation, that is virtually absent in the Soviet system. But even in the United States, industrial R&D is dominated by a small number of large corporations. Just 10 R&D performing firms account for more than a third of all expenditures, while the top 100 companies spend about two-thirds of the total.

During the past decade, moreover, both superpowers have been forced to adjust their S&T policies to meet broader national goals and new requirements. Many of the same concerns that have motivated policy makers and animated debate in Washington have also been keenly felt in Moscow. Primary preoccupation with questions of national security, which underlay the science policy efforts of both countries in the 1950s and the 1960s, has given way, more or less, to greater concern with applying science and technology to solve domestic civil sector problems. "Research applied to national needs" has become a new buzzword in American and Soviet official circles alike. The development of natural recources, energy, and the environment have emerged as major issues on the S&T agendas to an extent unanticipated in either country just a few years ago. Low economic growth and lagging productivity in both the US and USSR have stimulated increasing interest in formulating science policies oriented to industrial innovation. Indeed, the use of R&D, which both governments practically ignored in science policy in the past, is finally coming into focus in the US federal government and is assuming almost exaggerated emphasis in the Soviet Union.

In face of these changing conditions and new demands the adequacy of traditional policies and mechanisms is being increasingly questioned. In the US a new partnership in S&T is being called for between public and private R&D performers. Similarly, the Soviet regime has been pressing for a closer relationship between research and industry to achieve a more coordinated effort in the national interest. Both countries share a concern with the health of science and technology and debate how to improve capacity and performance.

In spite of some patterns in common, however, the science policy environments in the US and USSR are fundamentally different. Even apparent structural equivalents may mask basic differences in underlying philosophy, purpose, and operation. For example, the National Science Foundation, as a general funder and caretaker of basic science, resembles the USSR Academy of Sciences. There are strong parallels between the budgetary process, which is the main tool for planning, review, and control--at least in the public sector--in the United States, and the planning process in the Soviet system; and between the OMB and the GKNT in their executive management oversight and mediating functions in S&T matters. As the principal advisory arms in science policy at the apex of the two respective governmental structures, the OSTP and the GKNT play somewhat analogous roles. In interagency R&D coordination, the FCCSET is a kind of American functional counterpart to the GKNT. On a more general level, certain parallels may even be drawn between Congress and the Supreme Soviet as institutional arenas where S&T policies are publicly debated and legislated. But such national comparisons do not really take us far. Though some procedures or institutions look the same, their effects and significance may be quite different because they operate in different environments, each shaped by its own national traditions, values, and circumstances.

The main characteristics that distinguish the American and Soviet environments are rooted in the fundamental differences between a competitive market economy and political pluralism, on the one hand, and a centrally planned economy and political centralism, on the other. It is these underlying systemic dissimilarities that account for and shape the alternative approaches to science and technology in the two nations.

In the United States the S&T policy process is diffuse. The organizational structure of the federal government is highly fragmented and diversified with a multitude of crosscutting and competing agencies in both the Executive and Legislative branches concerned with S&T matters. In most of these bodies R&D is only an activity in support of a broader set of roles and missions. In the American framework no real mechanism exists to guide policy making and priority-setting, much less to blueprint and administer the whole enterprise. Science policy emerges not as a grand design but rather as the end product of a complex interaction of diverse and partial wills. The overall set of S&T policies lacks unity and coherence.

In the Soviet Union, on the contrary, there is a much more formal process, structure, and policy for science and technology. The set of institutions responsible for R&D planning and management is more explicit and functionally specialized; procedures are more uniform and clearly defined; and authority is hierarchical and centralized at the top. The whole system is built, in principle and aspiration, to produce comprehensive and unified S&T policies that are an integral part of overall macroeconomic plans and development strategies.

The roles and responsibilities of government, in particular, are perceptibly different. In the American setting government plays primarily an indirect and supporting role, serving as a catalyst to create a climate favorable to science and its applications. The system is premised upon a basic division of labor between public and private institutions as well as the belief that whenever possible private incentives and the normal play of market mechanisms should be relied on to generate relevant R&D and technological innovation. Only in those areas where market forces are deficient or where it has major responsibilities, such as defense and space, does government take a direct administrative role. The difference between federal markets and competitive private markets must be recognized. In the former the government frequently plans, funds, and manages directly the R&D and is also the principal customer of the results. The whole process is heavily authoritarian with strong emphasis on roles and controls, resembling that of the USSR with its one giant public sector and command economy. In the latter, the competitive private market, the government's role is only indirect. This is the major American market.

By contrast, the Soviet government takes generally an active and directing role in S&T policy and development. Just as industrial advance is the product of state initiative and administration, the spur to innovation also comes from central political authorities. Through state ownership of R&D results and detailed plans the government intervenes directly from beginning to end of the research-to-production cycle. Administrative bodies deliberately plan and introduce new products and processes. The mode of advance is predominantly innovation by order from the top down; administrative levers and bureaucratic instruments are relied on to drive the whole process. Thus the Soviet government stresses organizational and procedural solutions to science and technology problems.

It is important not to overdraw the image of two sharply dichotomous models of science and technology for the US and USSR. The Soviet system is neither as unique nor as monolithic as it is sometimes assumed to be. Though highly centralized, the S&T establishment is also heavily compartmentalized among numerous functional agencies and institutional subsystems. Although military R&D is systematically managed, Soviet civilian S&T is less centralized. The GKNT has only partially succeeded as general overseer by concentrating on a limited number of priority areas rather than all R&D activities. Nor is the American system as anarchic and freewheeling as it seems at first glance. Government regulation of innovation dampens the entrepreneurial spirit. Contradictory impulses and policies coexist in both environments. Each system excels in certain respects and falls short in others.

To underline the comparative dimensions of American and Soviet approaches, the following discussion focuses on three major areas of S&T policy: (1) relationship of scientific R&D to industry; (2) the use of indicators and measurement techniques in policy planning and management; and (3) incentives and obstacles to innovation. Finally, the new complexity barriers that both countries face today in framing effective policies will be briefly discussed. On both sides the problems promise to tax the imagination and ingenuity of political leaders and the broader scientific and engineering communities alike.

RELATIONSHIP OF SCIENTIFIC R&D TO INDUSTRY

The relationship of industry to scientific R&D differs significantly in the US and USSR. This industrial connection, moreover, affects appreciably the problems of innovation and diffusion in the two countries. In the United States industry plays two roles in influencing the conduct of R&D. On the one hand, industry sponsors, selects, performs, and utilizes the results of R&D. On the other hand, industry is the performer and user of R&D sponsored by federal government agencies. In a lesser role, industry influences what R&D is sponsored by the federal government through submission of unsolicited proposals and through the use of lobbyists to influence legislation.

In the Soviet Union, industrial enterprises perform little R&D; they influence the selection of only a small portion of the R&D, and directly sponsor only a minority share of R&D. Except in the newly developing associations, most scientific R&D is conducted in institutions independent of the production enterprises which ultimately use the results. Industrial enterprises do not appear to influence directly the State's selection of R&D to be performed, although they may influence their own industry R&D facilities through the intercession of central ministry management organs. In general, scientific R&D is an autonomous and closed subsystem in the USSR. The dominant focus has been on R&D as a relatively isolated entity rather than on the interplay of R&D with industry. R&D planning has been geared largely to the development of scientific and technical potential, that is, to the expansion of science and technology themselves rather than to the application of existing knowledge.

The creation and use of new technology is fenced off from general economic activity. Each sphere proceeds more or less on its own. Organizational structure and the overall planning process continue to reflect the fact that science and industry are still largely separate worlds, coexisting rather than interacting.

American R&D, on the contrary, is more closely coupled to other subsystems of society. Science for science's sake has not been an aim of public policy. Rather, like everything else, science should pay off if it is to merit public support. In government agencies, R&D is not considered in isolation but as part of their broad mission. In industry, management works on the principle that R&D of itself is not enough; it must ultimately be exploited in the marketplace. Thus, R&D is made a component of overall business strategy and operations.

A major consequence of the greater insulation of science in Soviet society is that R&D enjoys far more stability and continuity in the USSR than in the US. Kremlin policy makers have much more of an investment mentality toward S&T as growth enterprises than their American counterparts. The mode of incremental planning "from the achieved level" provides the Soviet S&T establishment an assured and rising level of funding that contrasts sharply with the variability of American R&D funding patterns. Neither the federal government nor industry in the US is officially committed to a base level of funding nor to standard levels of increase. On the contrary, R&D funding by industry varies widely with current economic conditions as does federal spending. In both the public and private sectors the vulnerability of R&D as discretionary outlays makes difficult the formulation of durable science policies. In addition, the Soviet practice of institutional bloc funding, as opposed to the American system of project funding, makes for much greater stability at the level of the R&D performer.

At the same time, this high degree of stability characteristic of Soviet science exacts its price.

Conservative tendencies stifle creativity and change. The inertia of institutions and projects is hard to break. R&D facilities and programs can go for years without producing any significant results. Above all, the isolation of research from production decreases technological innovation and causes problems in delivery. The American S&T structure, though not as stable, is more flexible and dynamic. The greater stress on results and ultimate use as well as the closer industrial connection keeps research and development both responsive and relevant to the changing demands of the customer. Though it does not permit the same security for performers and continuity for projects that institutional funding does in the USSR, the American mode of project funding coupled with external peer review provides a more independent and flexible instrument for terminating unproductive R&D and initiating new programs. In general, the market environment causes the research sector to make painful adjustments from time to time to direct capabilities to where they are needed.

The two systems differ fundamentally in their approaches to integrating research, development, and innovation. In the USSR integration is a bureaucratic function assigned to a hierarchy of special agencies. There is little direct collaboration among institutional R&D performers. Most external transactions are managed through superior ministerial offices and departments. Interorganizational linkages, therefore, are essentially administrative. The accent throughout is on hierarchical organization, extensive use of rules, multiple clearances, and long approval routes. Coordination across organizational boundaries and functional subsystems is particularly complex and difficult.

In the US the conduct and coupling of R&D take place under different operating conditions. The vertical relationship between organizations and plans for S&T activities is abbreviated because there are few steps in the chain of command between the setting of goals and the performance of R&D. Further, there is little coordination by the government between the determination of goals and objectives for departments and agencies and production activities in the private sector. Private firms compete for R&D contracts from government agencies and offer services that compete with those provided by the agencies themselves. The actors in American R&D are separate institutions, mostly nonhierarchical and relatively autonomous. They act independently and competitively, and come together by agreement in mutual self-interest. Linkage does not occur through directives and approvals but on the basis of competition and pluralism. Such cooperation of public and private institutions is one of the most original characteristics of the American science and technology enterprise.

These systemic differences underlying the architecture of linkage, in turn, shape attitudes of R&D personnel. In the USSR innovation by order and top down planning and management causes R&D performers as well as their supervisory ministries to look upward. They are oriented primarily to pleasing their own administrative superiors in the hierarchy. Since they are not concerned with the distribution and use of their results, producers all along the innovation chain are not output-oriented. They are, on the contrary, keenly concerned with inputs on the supply side because this is where major uncertainties and problems in innovation lie in the Soviet system. Furthermore, the emphasis on functional specialization and organizational separation tends to direct the vision of individuals and management bodies toward separate efforts rather than the overall enterprise. As a result the whole S&T establishment is inward-looking. Each performer takes a narrow view of his responsibilities, tasks, and interests.

In the American milieu of a highly consumer-oriented society generally and with market pull a major driving force for successful innovation, R&D performers are oriented outward, to satisfying their customers. Competition for customers on the basis of price and quality makes output and use important considerations. Supply is generally not a problem. Abundant resources are usually available, given sufficient capital. Rather, attention is directed to the demand side where in the American setting the basic uncertainties and risks are lodged. Individual and institutional actors focus on environmental externalities that may stimulate or constrain innovation, especially S&T activities beyond their own in-house efforts that may pose new opportunities or competitive threats.

Given these divergent orientations, R&D personnel maintain different patterns of communication and interaction. In the USSR functional performers tend to be separate from each other organizationally and spatially. The predominantly vertical structure of decision making inhibits lateral interaction. Working contact between R&D specialists and user or client groups is weak. The later links of the innovation chain--the introduction and debugging of new technology--are in particular poorly developed. Throughout there is little real interplay, much less team play, to integrate individual efforts. Self-sufficiency rather than cooperation is the goal.

The accent in American R&D is on direct interaction and interdependence among major performers. Continuing communication among the various participants promotes mutual understanding, trust, and acceptance. Though the "not-invented-here" sentiment exists, it is not so pervasive an attitude as it seems to be in the Soviet system. In the US personnel also move more both within and among the different sectors of academe, industry, and government. Close contact between generators and users of research is another important feature. Industry particularly stresses linkage not just in R&D but also between R&D and manufacturing, marketing, sales, and services. These connections help assure the viability of new products and processes. Some firms organize R&D to involve the user early in the development of innovations and clients also participate at critical points. Good will and good customer relations, it is said, do more for technological utilization than almost anything.

Taken together these features point to different approaches to technology transfer. In the USSR communication takes primarily the form of the transmission of documents and routing of information through formal administrative channels. The main interactions are between functional performers and higher ministry authorities who serve as administrative gatekeepers at critical transfer points. The whole activity chain moves through different links and stages by hierarchical referral and bureaucratic relay. In general, the research-to-production cycle is not an integrated or integrating process.

In the American framework emphasis is on person-to-person contact rather than reliance upon printed information and communication through a middleman. Informal and oral sources provide key communications about both needs and technical opportunities. Bridging roles are played by "technological gatekeepers," "market gatekeepers," and "manufacturing gatekeepers," all of whom provide information about environmental conditions that can influence the flow of action. This close linkage allows scientists and engineers to cooperate in shaping technical programs and an information base. Feedback from the market plays a self-correcting role and keeps R&D responsive to the user.

This brings us to the question of technology utilization and delivery mechanisms. These mechanisms differ between the private and government sectors in the US. The federal government, despite its large investment in R&D, does not take an active role in R&D diffusion and has not, with a few notable exceptions, been effective in promoting it. Diffusion is largely the province of the private sector. Most federal agencies do not have explicit policies or special programs for promoting technology transfer. Those that do usually fall short of the utilization stage. Among the mechanisms used by federal agencies the most common and expensive are the S&T information dissemination services. They are also judged to have the lowest impact, reflecting the general ineffectiveness of written communication as a means of technology transfer in the American setting. The most successful approach, on the other hand, has been the highly active Agricultural Extension Service where field agents know well the local users and serve, in effect, as salespeople for new technology.

All these governmental programs encourage research utilization only after the R&D results have been generated. Most effective industrial approaches to technology utilization, however, begin much earlier in the innovation process. Industry also provides an integrated and coordinated system from conceptualization to commercialization that does not exist in the governmental sector. Indeed such an approach is used in the public sector only in areas like defense or space when the federal government both creates and defines the market and is the principal customer itself. Even here, however, systems planning and management is not always efficient or economical.

The practical translation of R&D results is one of the most deficient areas of S&T policy in the USSR. Traditionally, Soviet economic policy has minimized investment in an experimental base and scientific instruments industry in favor of investment in on-line production facilities. The development sector, the crucial intermediary between research and production, tends to be neglected. The share of expenditures on development and engineering applications has been only about two-thirds that in the United States. As a result there continues to be a scarcity of experimental facilities to develop and test prototypes.

In general, the vital interfaces in the transfer process have not been explicitly and effectively structured or linked. The utilization of R&D has fallen outside the bounds of both science planning and production planning. Innovation or the introduction stage has not been an organic part of the system of planning and administration. There is no special purpose organization charged with managing diffusion in the Soviet Union. For the most part, extensive--but ineffective--S&T information storage and retrieval systems have been relied on. These services, which are managed and coordinated centrally, befit the general pattern of Soviet communications.

Since the late 1960s Kremlin authorities have shifted from passive mechanisms to more active strategies of technology transfer to enhance industrial research utilization. Adopting a process view of innovation, they have established new institutional arrangements and organizational forms that seek to span and integrate the multiple participants and stages in the innovation cycle. The development of research complexes along the lines of some American industrial research parks has been emphasized in the belief that the desired benefits of cross-fertilization, sharing of facilities and interdisciplinary cooperation are better achieved through such close association. Different types of research complexes have evolved, including (1) formal incorporation of research, design, and production facilities in single organizations, such as the production and science-production associations, and (2) more recently, geographic collocation of R&D facilities. The creation of special organizations concerned with the introduction of new technology is less well advanced. Forms of project management and matrix organization used in American R&D are, however, being modified and tried in the Soviet context.

SELECTION OF S&T GOALS AND EVALUATION OF RESULTS

In the United States major goals (problems) needing S&T solutions are selected not as a formal planning activity but through a complex political-economic process that is not well understood or economically efficient. No formal procedure or time schedule exists for such selection, no one body to establish goals and to measure results. Both the Executive and Legislative branches have identified such major goals as space exploration, cancer research, improved environmental protection, and energy research and development. In general, the mission agencies of government have assumed responsibility and authority for recognizing scientific opportunities and for stewardship. Given the decentralized nature of American R&D neither the selection of topics nor the allocation of funds is a simple process in government. The fragmentation of structure and competence mediates against comprehensive policy planning and analysis.

In the US the budget process represents the closest thing in government to a systematic effort at resource planning, program evaluation, and integration. But it is a highly imperfect tool. There is no special budget or special budget process to integrate R&D into a broad S&T policy or national goals. Rather, the budget is prepared and judged on a departmental basis; the total federal R&D budget is largely an after-the-fact-summary of the R&D budgets requested by each agency and justified in terms of their separate missions. The multitude of agencies in the Executive Branch concerned with S&T matters is matched by a multitude of committees in Congress that share responsibility for budgetary analysis and appropriation.

This pluralistic method of budgeting for R&D makes difficult the formulation of policies and coordination of activities across traditional government sectors and independent agency lines. Although some efforts are made--largely by the OMB and, to a lesser extent, by the OSTP--to ensure priorities and balance in S&T programs, no integrative mechanism draws science policy toward a rational approach to problems of choice, of costs and benefits, of needs and opportunities. To be sure, the need is generally recognized for some central focus and oversight to ensure greater consistency and coordination among plans and agencies. Regardless of how compelling the case seems for more systematic S&T planning and evaluation, however, the basic fact remains that such a planning and analysis function does not fit easily into the pluralistic form and competitive ethos of American government with its fundamental emphasis on political advocacy, bargaining, and compromise in reaching public decisions. The capability for such policy analysis and integrated systems management exists only in exceptional instances where the nation has been galvanized towards a single goal or where a single national project has the general consent of the populace. For the most part, decisions are made piecemeal. Throughout the process there is considerable confusion and disagreement, but the nation accepts these inefficiencies and imbalances as the cost of diversity and of decision making that values open markets, adversarial relations, and consensus building in public policy.

In the Soviet Union the planning of R&D is highly structured in a top down manner. Most important S&T goals are formally identified and selected. Currently, this list consists of approximately 200 major problems. The solutions to these problems are scheduled over periods of from one to three five-year increments and are incorporated into the macroeconomic plans for the USSR as a whole. Not only do plans specify general objectives, but they also detail all measures necessary for the attainment of goals, such as requisite resources and their interrelationship, experimental design, assignments for output and technology transfer, construction of new facilities. In addition, the mechanisms for plan expression and enforcement, such as indicators, norms, standards, and incentives, are similar at all levels and in principle are mutually reinforcing and internally consistent. In the USSR, then, the whole structure of hierarchical relationships is designed to integrate the various activities of different units around centrally determined general goals. Thus, in principle at least, the Soviet system offers great potential for comprehensive planning, coherent analysis, and balancing assessments in S&T policies.

In practice, however, Soviet R&D planning suffers from serious deficiencies. Some of these result from the inherent uncertainties and unpredictability of innovation itself. Others are deeply rooted, however, in Soviet organization and procedure. Though highly centralized, policy planning and analysis is heavily compartmentalized not only in vertical branch ministries but also in the numerous special functional agencies. The innovation cycle is fractured in time, task, and territory. The basis of planning, financing, and management is still primarily the functional-institutional performer rather than programs, projects, and work stages. Furthermore, S&T planning is also separate from and insufficiently coordinated with the planning of production.

Much as in the US, therefore, it is difficult for central S&T policy makers in the USSR to exert integrating influence upon a basically pluralistic administrative structure. The heavy chalk marks which delineate different bureaucratic subsystems and institutional domains are not easily erased. To be sure, there are more deliberate attempts than in the US at overall priority-setting, program assessment, and coordination. But the capabilities of the GKNT--the main balancing wheel of the Soviet S&T mechanism--and other functional agencies to analyze and evaluate alternative program goals, costs, and benefits are constrained at every turn. They frequently lack the authority and means to perform their integrating functions. Given the nature of their overlapping and shared responsibilities for R&D planning and management, the state committees are often forced to seek the approval of and accommodate themselves to various ministries, departments, and other state committees, not to mention Party agencies. As a result they perform a continuous and difficult balancing act in which national goals and priorities are reconciled with the special interests of the numerous organizations that conduct the national R&D effort.

The Soviet planning process, then, like the American budget process is salted with bureaucratic rivalries. Though calls are periodically heard to strengthen the integrative capabilities of the GKNT, there is still little inclination to give the State Committee or any other body the clout necessary to forge coherent, focused programs across ministerial and departmental lines. To do so would require an accommodation with Gosplan, the Academy of Sciences, and the whole machinery of government that could not easily be achieved. Problems of interagency coordination and cooperation therefore remain unsolved. The Kremlin continues to experience considerable difficulty in building a uniform national S&T strategy, unity of purpose, and commitment that transcend the parochial preferences of each player.

Generally speaking, both nations have been unable to impose a long-term view on R&D planning and analysis. In the United States the annual budget and a four-year Presidential term make long-range projections in the public sector difficult. Lacking assured R&D funding, individual agencies tend to respond to short-term needs and pressures and to neglect long-term programs. American industry, too, operates on a short time horizon. Industrial management is largely preoccupied with immediate markets and short-term profits as distinct from longer range payoffs from R&D with its attendant risks and uncertainties. Long-range, dedicated innovation often occurs by accident through the actions of deviants.

Despite explicit emphasis on and formal procedure for long-range planning and forecasting in the Soviet Union, Kremlin authorities have also not been able to develop a strategic approach to S&T policy. The planning of R&D has been oriented to building up S&T potential; a focus on specific goals and end use has been lacking. The planning of technological innovation and utilization has been geared to solving current production tasks. The two spheres of activity generally are decoupled. The R&D plan has been essentially an appendage of the general macroeconomic plan, and insufficiently integrated with it. Though we tend to associate Soviet economic decision making with "five year plans," planning in the USSR really proceeds in one year intervals. The Soviet budget is also an annual budget. A tendency to plan from the achieved level and a predominantly incremental style of decision making hold sway throughout the system.

In the USSR, too, the present tends to drive out the future.

Steps have been taken in recent years to broaden the vision of Soviet S&T planners. The five year plan has indeed resumed importance as authorities have put increased stress on careful and comprehensive formulation of goals over longer periods to concentrate resources better on priority projects and provide greater direction and control over the nation's R&D effort. A fifteen-year program has also been drafted for the development of science and technology for the period 1976 to 1990. This program is designed to serve as the organizing framework for a broad 15-year development plan for the economy as a whole. This general macroeconomic plan has not yet appeared, however, testifying to the continuing difficulties that beset the drafting of feasible long-range Soviet plans. The framers of the S&T program, moreover, have also been ordered to rework their forecasts. Obviously, the proper formula, political and analytical, has not yet been found for striking a balance between present interests and future needs.

By and large, then, the science and technology enterprises in both the US and USSR run on momentum and incrementalism. With tight constraints on zero-based budgeting and programming and a short time horizon, these tendencies cause both systems to remain input-oriented rather than output-oriented.

The Soviet system is particularly incremental. The tendency to plan from the achieved level reflects an "add on" approach to design that encourages scaling up existing processes rather than developing new ones and sees continuity as the best guarantee of meeting planned output goals. The S&T plans themselves endorse incrementalism. These plans, once approved, carry the force of law; there is little flexibility between planning periods and the cumbersome process of revising plans produces rigidity and little opportunity for quick remedial action within the periods. The plans are most rigid at the higher levels, with only limited flexibility at the level of the institute, design bureau, and individual researcher. In the US, however, S&T activities are highly flexible, responding to changing conditions at all levels from the national to the individual research scientist. The innovation cycle is more sequential and dynamic than in the Soviet Union, with more review and reevaluation as development proceeds.

Neither the US nor the Soviet Union has mapped any firm normative rules or fixed indicators to guide strategy and policy development in science and technology. Until recently in both countries, science and technology had generally unrestrained standards and unlimited drawing accounts. The need for constraint was seen in the US in the 1960s. In the 1970s, the Soviets tried to define a set of "basic indicators," such as the technical and economic indicators established by Gosplan in 1974, but these are incomplete. The measure of inputs remains by default simultaneously the measure of output because of the absence of any precise norms for planning and allocation. Yet the need for standards is real. Three general criteria are being used: technical, economic, and social. Technical considerations have been foremost in both the US and the USSR. The S&T effort has focused on big military, space, and nuclear programs. With such programs, science policy has enjoyed the advantage of being stable and specific, limited to a small domain of government activity and particular projects.

Increasingly, however, science policy has needed to reflect the social and economic effects of technical progress. In particular, national attention in the US is focusing on the implications of technological change for the environment, health, and public safety. Government regulation in these areas has expanded greatly, to the point where private industry feels a threat to its own S&T initiatives. The economics of S&T are also being stressed, although no clear market or economic criteria for federal funding of civilian scientific R&D have been developed. A government agency's relative isolation from the marketplace also suggests the need for new mechanisms to link more effectively the funders, performers, and users of R&D.

By comparison, the Soviet system responds even less to popular attitudes and market forces. Faith in the intrinsic desirability of science and technical progress has not diminished in the USSR as it has in the US. Consequently, Soviet policy may pursue projects like the TU-144 supersonic transport and a continuing large-scale space program which embody advanced scientific, technological, or design solutions that might be vetoed in the American setting by commercial considerations or popular demand.

Nonetheless, since the late 1960s Kremlin authorities have become more aware of constraints on resources and concerned about effectiveness of their use. While environmental impact statements have not yet become mandatory in R&D planning, the importance of ecological factors is on the rise. Above all, economic considerations have become prominent; all proposals for R&D projects must be supported by calculations of economic return redounding to the users of the new technology and to the economy as a whole. The main aim of this requirement is to weed out nonpaying, impractical R&D and to raise the cost-effectiveness consciousness of the S&T establishment.(The requirement, however, is often not observed) The economic orientation of the basic indicators for planning S&T progress, issued in 1974, is also clear. With emphasis on accelerating technological innovation and raising production efficiency, these indicators seek explicitly to couple more effectively S&T policy with economic policy, the planning of R&D with the planning of production.

Of course, economic return has long been the main criterion used by American industry in selecting R&D pursuits. For industry the problem is chiefly one of assessing the long-term potential of a product line. This typically involves such factors as actions of competitors, market size and segmentation, government regulatory policies, image, corporate objectives, budgetary limitations, needs of production operations, and definitions of the lines of business in addition to purely technical considerations. Market research and information on user needs are essential elements in effective research planning; industry remains convinced that reliance on strictly rational components and technological opportunities are doomed to failure.

Although the criteria for both countries can be grouped as technical, social, and economic, they are defined differently in the two systems, and thus have different practical significance. The differences in S&T policy are rooted in the difference between a bureaucratic system of planning and evaluation and a market system. In the USSR an administrative bureaucracy defines the relevant criteria and judges success on the basis of how well organizations meet multiple plan targets for output, costs, and profits as defined by formal rules. In practice, these rules have no necessary relation to the efficient use of resources, which are economized only incidentally in response to explicit instructions and definitions. Prices are also set administratively in an arbitrary and autonomous manner. In effect, Soviet R&D performers face neither true output markets nor true input markets. An organization's performance is not evaluated in any market external to the organization but directly and immediately by administrative superiors on the basis of how well it seems to be meeting planned objectives.

In the United States the market largely determines choices especially in industry. Specifications for success are set by the customer, not by an administrative boss in some government office. The market test is a comparison of one firm with another in the same field. Success depends on the behavior of one's competitors as well as one's own performance. Thus, a private firm may achieve its production, sales, and cost goals and lose money, or it may fail to meet its goals and yet do better than its competitors. The ultimate test is survival in the market. Conversely, a Soviet organization may meet its plans and be rewarded but be less profitable and innovative than other organizations. It may underfulfill its plans but be more efficient than other organizations. In American business evaluation rests largely at the bottom line: profit in the market. In government there is no comparable bottom line. To a large extent, it is the appearance of success that counts, much as in the Soviet environment generally.

Soviet criteria have, then, an artificial quality. Though several economic levers, such as cost, price, and profitability, are used, they become transformed essentially into administrative levers. There is also no acceptable criterion of fulfillment, no entirely satisfactory measure of research and innovative output. The economic effectiveness of proposed R&D is calculated mainly to award bonuses rather than to decide whether to undertake the R&D in the first place. Decisions regarding evaluation and incentives, moreover, are taken predominantly on the basis of planned or estimated economic return, not on real results and savings. The link between economic benefit and bonus awarded is tenuous. Though calculations of the actual economic return are, in principle, to be made following the application of R&D results, they are in practice rarely computed or recorded. The quality of planning and performance are judged only in terms of the plan itself; the planned targets become the evaluative criteria. Hence, a real need exists to build evaluation and adaptation into the Soviet planning and assessment process.

In sum, both countries have made progress in broadening and refining the criteria for planning and managing R&D. There are still difficulties--the uncertainties inherent in the R&D process; the lack of generally accepted methods of evaluating the results, effects, or benefits of R&D; gaps in information; loopholes in procedure; the growing complexity of R&D projects. American and Soviet decision makers alike are reaching for more sophisticated analytic techniques to improve planning and resource allocation, to specify objectives, and to evaluate alternative ways of accomplishing these goals.

In the United States several specialized planning (e.g., PPBS) and project management (e.g., PERT and CPM) methods came into use during the 1960s. They were designed primarily for large development programs in aerospace and defense-related fields--that is, in sectors which operate much like command economies. The magnitude and complexity of these programs demanded sophisticated and high-capacity management control systems. Although only the largest companies and the military use PERT techniques and only on the most complex projects, systems thinking is a prominent feature of the research management environment in general in the United States. The inherent uncertainties in R&D and the difficulties of trying to quantify social benefits, however, generally rule out the application of highly quantitative systems planning and management techniques.

In the USSR a similar systems movement burgeoned in the 1970s. The demand for techniques which view projects in a total systems perspective began to be clearly felt as the regime launched a number of crash development programs to speed technological innovation. Formal program-type planning methods appeared along the lines of PERT and other sophisticated American models. These techniques were developed, in particular, for application in the complex interbranch S&T programs of national priority, which previously suffered from faulty systems planning and management, and to improve management effectiveness in general.

Such sophisticated planning and control techniques are compatible with the Soviet predilection for highly structured activities. Used for some time in the defense sector, such methods have not generally been applied in civilian R&D which is constrained by the structural and administrative fragmentation of the research-to-production cycle. Formal procedures for multiagency planning, financing, and management are still confined largely to the interbranch programs and complex projects, although a few ministries have also introduced systems planning and programming into their intrabranch operations. Simple evaluative methods and manual calculations are on the whole preferred over highly sophisticated analytic techniques and complex mathematical formulas. By and large, the abacus, not the computer, remains the standard tool.

In both countries, then, scientific R&D still falls generally into the realm of poorly structured decision problems for which modern systems analysis and scientific management techniques are not very useful. Such formal methods have been mainly reserved for massive development projects, especially those resulting in the production and operation of advanced hardware. The unpredictability of fundamental and some applied research resists planning and control by such methods. Decision makers in both countries will continue to rely on a mix of formal and informal instruments, evaluation by colleagues, and subjective experience. In short, science policy in both nations will remain an inexact science.

INCENTIVES AND OBSTACLES TO INNOVATION

The basic systemic differences between the two nations foster divergent approaches to another important area of science policy: incentives and obstacles to innovation. Though the United States and the Soviet Union both have special policies and mechanisms in direct support of innovation, indirect influences are probably more significant. Forces and government policies bearing on basic economic activity have an effect as well on R&D, whether intentionally or not. By shaping the general economic climate and value system of management, broadly aimed government actions can stimulate or constrain innovation. Policies devised explicitly to promote technological advance or to guide its direction may, in fact, have relatively small influence.

This trend holds for both countries but for very different reasons. In the US innovation is more closely woven into the whole economic fabric and culture of the nation than it is in the Soviet Union. The industrial connection is a close one, and American R&D, therefore, is powerfully influenced by the general condition of industry. In the USSR general economic policies are of overriding importance precisely because of the separation of R&D from production. Science and technology have not been driving forces of the Soviet industrial machine. Indeed, the production sector strongly discriminates against innovation. The supplementary guidance system of special agencies, plans, budgets, and incentives oriented to the advance of S&T still stands largely apart from the primary guidance system for basic economic activity. Science policy continues to have little appreciable impact on the normal processes of economic life in the USSR.

At issue in both systems is the problem of balancing the risks and rewards associated with innovation. The balance rests on profits tied to the market in the American setting and bonuses tied to plan fulfillment in the Soviet. Both company profits and enterprise bonuses vary with general organizational performance, as do the rewards to management. Hence, Soviet industrial managers tend to maximize bonuses as their American counterparts maximize profits. In neither country is the management reward structure attuned to the pace of innovation. Both American and Soviet management work with a short time horizon, and each tends to fall into a profit-NOW and bonus-NOW syndrome. Orientation to production means that innovation consists largely in the adoption of less risky, small size cost-reducing processes rather than the creation of basically new products. Moreover, the problems of innovation in both countries lie not so much in internal management as in relations with outside organizations, principally with suppliers in the Soviet Union and with customers in the United States.

On the whole, the balance of risk and reward in the USSR still tends to work against innovation. Although the bonus indicators and decision time frame have been modified recently to make them more hospitable to innovation, these adjustments have not yet significantly altered the rules structure in favor of technological change. Indeed, the new incentive system itself has become so complex that management is probably more uncertain than before about just what consequences and rewards may be expected from alternative choices. There are still no precise rules to guide decision making. The problem remains one of trying to decide which of the many assigned tasks carry the most weight in the minds of one's superiors and must be attended to. In general, the primary success indicators still revolve around the fulfillment of output-related rather than innovation-related tasks. Innovation continues to risk failure to meet the fulfillment of plan targets for output and brings few rewards for success. Indeed, bonuses for new technology usually do not compensate for the decline in primary bonuses that inevitably comes with innovation, at least not in the short run. In sum, the special incentive programs for innovation in the USSR still do not provide a real counterweight to the general incentive structure designed to support current economic production and technology. The two incentive systems continue to coexist and to contradict each other.

In the United States as well innovation continues to be a difficult and dangerous business with a high failure rate. Indeed the balance of risk and reward seems to have settled increasingly on the side of constraint as the general rate of innovation fell in the 1970s. The major barriers are still market-related uncertainties. Increasing uncertainties about government regulatory policies and future rulings also adversely influence market behavior and private S&T initiatives. The growing burden of regulation over the past decade, in fact, has perceptibly slowed the process and increased the cost of innovation in several areas. Given these uncertainties, management usually finds alternative investments that can yield a potential return equivalent to that of R&D and at far less risk. Nonetheless, the rewards for successful innovation are substantially greater in the United States. The American system provides better the opportunity, the capacity, and the pressure to innovate than the Soviet system in which innovation continues to be looked on mostly as a burden or unnecessary nuisance.

Each system, to be sure, offers certain intangible benefits, but even in the USSR the terms of competition between innovational activity and other alternatives are increasingly economic. Indeed, the share of bonuses in managerial income has been steadily rising since the mid-1960s and are a stronger incentive in decision making today than ever before. Differences in national attitudes towards property, however, affect significantly the structure of economic rewards for innovation in the two systems. In the United States private ownership of the results of R&D--and the associated opportunity for major economic gain--creates a powerful incentive to the individual and to the firm. The American patent system, moreover, confers a temporary monopoly during which time the inventor or innovator can exploit his ideas and protect his competitive edge. Indeed without the protection provided by patent rights many entrepreneurs and industrial firms will simply not take the risks involved in innovation. By contrast proprietary rights over all R&D results in the USSR are held by the State. The inventor or innovator is compensated with a lump sum payment which cannot exceed some fixed maximum. For a single invention the upper limit is 20,000 rubles. Statutory ceilings are also fixed on individual bonus earnings of all kinds so that a person may not receive more than a certain percentage of his base salary. Nor can a person receive in innovation bonuses in any one year more than 1200 rubles. Only planned innovations, moreover, not unplanned ones, are eligible for bonus awards. Indeed there are upper limits on virtually every part of the incentive structure in the Soviet Union. Bonuses for innovation relative to rewards for non-innovation alternatives are also not sufficiently large to provide an effective incentive for a high rate of technological change. In general, the incentive system still rewards competent but conservative management and offers little for innovation.

On the other hand, penalties for non-innovative behavior are also much greater in the US than in the Soviet Union. Part of the reason lies in the basic dissimilarities between a competitive market economy and a centrally planned economy. In the US, competitive market pressure is a principal driving force behind innovation. If a firm does not respond to the threat posed by the introduction of new technology by competitors, it may not only lose its share of the market but indeed be eliminated altogether. In the US technological change is a major cause of dissolution or bankruptcy of firms. As we have noted, a firm's performance is ultimately judged on the basis of not only its own innovative behavior but that of its competitors as well. The need to keep up with, if not ahead of, innovating competitors literally forces American business to innovate.

The Soviet system, however, lacks strong sanctions for failure to innovate. The kinds of built-in competitive pressures that exist in the American market economy are not present. There is competition, it is true, but socialist competition is a carefully controlled exercise in which everyone competes according to plan. There are only winners--and no losers, since losers really lose nothing. Today sanctions imposed when plans are not fulfilled are rarely more severe than modest monetary penalties. The plan for new technology continues to be the one plan in the USSR that is consistently underfulfilled. The economic viability of the non-innovating enterprise is not automatically threatened by the decision not to innovate. Soviet enterprises do not go bankrupt or out of business. Inefficient plants are not placed in a severely disadvantageous position in relation to innovating establishments. On the contrary, the opposite holds. Just as there is a ceiling on the available rewards for successful innovation, there is also a floor to cushion the risks of failure. The organizational structure protects producers against losses from both their own unsuccessful innovations and the successful innovations of others. Fundamentally, a Soviet organization competes not against other facilities but instead against its own past performance record. In accord with the principle of planning from the achieved level, its targets are set predominantly in relation to its own earlier institutional results. This also explains in part why the rate of diffusion of innovations is also lower in the USSR than in the United States. New products simply do not drive out old technology under Soviet operating conditions as rapidly as they do in a competitive market.

Finally, the two systems differ in their capacity to accommodate and discharge the innovation function. In the US large companies are frequently not good at innovation. They exhibit, in fact, the same kinds of vested interests in and preferences for established products and processes, set styles of organizational behavior, and conservative management outlook that characterizes many Soviet organizations. The key role in innovation is played by the small company or technological entrepreneur that is able, again and again, to break into the system with new technology and techniques. Although relatively good at innovation, the entrepreneur or small business, however, generally lacks the capabilities to mass produce and market the innovation. These skills lie with the large companies that often become major customers for the high technology products of the small ones. The large companies may also buy the small company since the risk of the established new technology is now diminished. Such a merger permits the parent company to evolve and renew itself. In general, then, the small innovating firm introduces a healthy competition to established companies.

In the USSR such a healthy symbiotic relationship does not exist. Indeed, the system does not provide the conditions of entry whereby the technological entrepreneur can easily emerge, much less succeed, outside the network of established institutions and arrangements. Under traditional operating practices individuals and organizations who are both capable of and interested in effecting the transition of scientific results into application have been lacking. The task of innovation has generally fallen outside the domain of either R&D or production facilities. The critical functions have not received the management attention they deserve. To be sure, the Soviet Union has demonstrated the ability to innovate, but usually in a few select priority areas. It has not demonstrated a capacity for technological innovation along a broad front. In general, the development of a new product requires either breaking into the system with the support of higher authorities or creating new organizations outside the regular channels. On the one hand, the rigidities of the existing system of planning and management are eased by the priority attached to the innovation; on the other hand, they are bypassed altogether. The system simply does not accommodate easily unplanned and unsponsored innovations from without and from below.

INSTITUTIONAL RESPONSES TO NEW COMPLEXITY OF S&T PROBLEMS

Science policy is acquiring enhanced importance in both the US and the USSR as each rests its future largely on progress in science and technology. Many of the pressing problems facing both countries today have strong S&T components as part either of their cause or of their solution. Science and technology are giving new direction and shape not only to national policies but to the international relations of the two superpowers as well. What stands out about the interactions of science, technology, and society is that they are becoming increasingly complex and highly contingent in both systems. The major challenge before American and Soviet policy makers alike, then, is how to integrate their science and technology enterprises to match the complexity of problems to be solved.

In neither system, however, are present mechanisms well suited to solve contemporary S&T problems. Each nation has evolved over the years a relatively settled division of responsibility among an array of special administrative agencies and separate performing institutions. But the problems and the solutions in science policy today cut across established boundaries. Effective problem-solving requires a high level of coordination and cooperation. The multiple participants in the innovation process need closer relations that still recognize their distinct roles. The creation and administration of such linkages, in turn, demand of both systems a new level of management and of imagination.

Though both nations are beset by the mounting complexity of S&T problems, the nature and source of complexity differ in the two systems as do their evolving institutional responses to overcome the new barriers. In the United States both the public and the private sectors--and their interaction--are growing more complex. This complexity acquires added significance as science policy focuses increasingly on solutions of domestic civil sector problems, requiring a more diverse and less centralized approach than military and space problems. The role of the federal government and of industry in public technology and methods for stimulating innovation to improve the quality and efficiency of public services are unclear. In particular, government regulation has grown as a national concern. The proliferating demands and standards imposed by government and the costs of regulation are beginning to inhibit seriously both university research and industrial innovation. Reform efforts are underway to rationalize the whole regulatory process and to make regulation itself cost-effective by introducing and requiring economic analysis and attention to costs in regulation. Underpinning regulatory revision is the need for new approaches to achieving a better balance between risk and benefit. Nonetheless, basic knowledge about the factors involved is still weak, and there is no agreement about how to measure the costs and benefits associated with this new set of S&T problems.

The Soviet Union also faces new complexities in creating an integrated approach to technological innovation in the domestic civil sector, especially the economy. Integrative capabilities, both analytical and administrative, are much more deficient in civilian than in military R&D. The problems of securing collaborative and coordinated actions across departmental boundaries are particularly complex and difficult because of the strongly vertical axis of the Soviet system. Yet such cooperation will be necessary to accomplish the numerous interbranch development projects and massive modernization programs required to solve domestic problems. The bureaucracy of government is not congruent with contemporary S&T problems. But Kremlin authorities hope that modern management methods and systems engineering can provide solutions. Given the importance of bureaucratic levers in driving the Soviet innovation process, improvements are being sought through new administrative measures. Although the project planning approach might be good for certain specific programs, it does not seem to be suitable for R&D as a whole. The relevance of R&D to achieving industrial efficiency and quality must be assured; at the same time, the general health of science and technology must be maintained. Soviet science policy simply did not have to address these issues, at least not in present terms, earlier.

In their approaches to contemporary problems of science policy design and management, both superpowers seem to be experimenting to some extent with practices of the other. In the US there is growing concern with centralizing certain functions, such as data storage, while in the USSR attempts are being made to introduce some form of competitive pressure and greater local initiative to stimulate decentralized innovation and diffusion. Each system is seeking a new balance between centralized and decentralized modes of operation without altering, however, its basic system design and approach. As we have seen, many differences between the two systems are rooted in fundamental differences in management philosophy, property relations, and social values. These factors tend to rule out certain practices altogether and circumscribe the possibilities of change. It is evident, however, that improved understanding in each country of the other country's approaches is valuable in its own right and creates the opportunity for each to benefit from the other's experience and collective knowledge of its citizenry. And with greater mutual understanding it may be possible for both giants to cooperate in solving some of their mutual transnational problems through science and technology.

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